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JOURNAL OF THE AERONAUTICAL SCIENCES

Volume 5 JANUARY, 1938 Number 3

Flight Experiments on the Boundary Layer

B. MELVILL JONES, *Cambridge University, England*

First Wright Brother's Lecture
Presented before the Institute of the Aeronautical Sciences at Columbia University, New York
December 17, 1937

Foreword

This lecture is to be the first of a series to be delivered annually in honour of those famous pioneers the Wright Brothers. I am told that the lecture itself should be severely technical and should not deal in compliments, but it is right for me to record, before beginning, the deep admiration which I have always had for Wilbur and Orville Wright, ever since the time when they were the half mythical heroes of my school days. I am acutely aware of the honour which you have done me in asking me to inaugurate a series of lectures in their honour. I shall not discuss the work of the Wrights, which is familiar to all, and it would be an impertinence to attempt elaborate praise of men whose names will remain household words when I and the majority of those present have been long forgotten.

Introduction

THE authorities of the Institute of the Aeronautical Sciences have decided, so I am instructed, that the Wright Brothers' Lecture should deal with subjects upon which the lecturer is engaged at the time, rather than with a general survey of some wide branch of aeronautical knowledge. This decision has the advantage that the lecturer is actively interested in the subject about which he talks, but it leaves to chance the question whether he is in a position to end his lecture with simple and clear cut conclusions. I mention this because the problem upon which we are working at Cambridge, and about which I shall speak, is not yet solved and my lecture must, perforce, be confined to a discussion of aims and methods and of results so far obtained; it does not contain that simple statement of conclusions which is the ultimate aim of all good research. After this explanation you will not, I hope, be disappointed when the lecture ends on a note of interrogation.

The material from which the lecture has been constructed is drawn mainly from experiments made in flight at Cambridge, but in order to make it as complete as possible, results from Government Research Establishments with which we work in close cooperation are quoted. For permission to do this I have to thank the British Air Ministry and the various persons directly concerned. I have also to thank the British Aeronautical Research Committee for permission to use information which has been submitted to them but which, at the time of writing, has not been published.

The title of the lecture is *Flight Experiments on the Boundary Layer* and it deals more specifically with the transition of the layer from the laminar to the turbulent form. Everyone interested in modern aeronautics is of course well aware of the general field of knowledge surrounding this subject; that the resistance to motion, of modern aircraft arises mainly from the friction of air acting upon exposed surfaces; that this skin-friction, as it is called, is applied in a comparatively thin layer of air immediately overlying the exposed surfaces; that these "boundary layers" in the air take one of two forms, a smooth or "laminar" form near the front of the exposed surface, and a turbulent form towards the rear; finally, that the friction of the laminar layer is much less than that of the turbulent layer, so that the

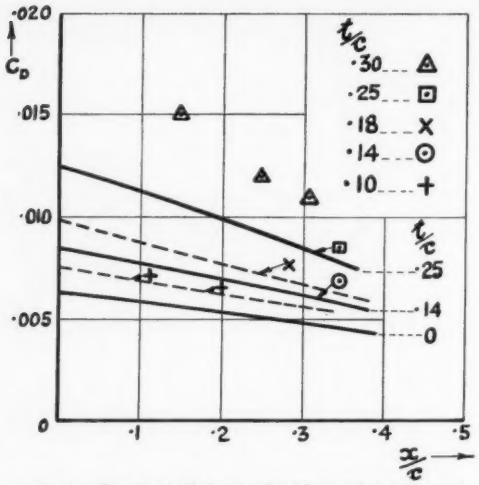


Fig. 1. **Drag coefficient related to point of transition.** Ordinates represent conventional profile drag coefficients. Abscissae show the mean values of the distances x from the leading edge of the points of transition from laminar to turbulent flow on the upper and under surfaces of various wings. The distance x is measured parallel to the wing chord which is of length c. The maximum wing thickness is represented by t. The drag coefficients shown by the curves are computed as described in the text. The figure relates to a wing Reynolds Number of seven millions and slight adjustments of the order 2 percent to 3 percent have in some cases been made to the observed drag values, to allow for the fact that they were obtained when the Reynolds Number had values ranging from five to eight millions.

mean friction coefficient of the whole exposed surface—the figure used by the designer in laying out his performance chart—depends upon the precise location on the surface of the line at which transition occurs.

The order of magnitude of the changes which occur in the drag of a smooth wing, when the point of transition from the laminar to turbulent flow moves forward or backward along the wing profile, is illustrated in Fig. 1. Here, ordinates represent the conventional profile-drag coefficient and abscissae relate to the mean distance—measured parallel to the wing chord—between the leading edge of the wing and the points where turbulence begins on the upper and lower surfaces, respectively. The drag coefficients were obtained in flight by the now well known method in which small pitot and static-pressure tubes are made to traverse the wing wake; the transition points were located by methods shortly to be described. The use of the mean transition point as a basis for plotting is open to objection because the velocity distributions on the two surfaces are not in general the same, but some sacrifice of precision is justified in order to bring the various results together on a simple diagram suitable for a preliminary survey of the situation. The precise positions of the points where turbulence was found to begin on each surface in various circumstances will be considered later.

The individual points in Fig. 1 relate to wings of various thickness, with lift coefficients between 0.3 and 0.4; the crosses relate to experiments made at Cambridge, and the other points to experiments made by the Royal Aircraft Establishment, Farnborough. To obtain the two points for the wing of thickness ratio 0.10 the point of transition on the upper surface was fixed at $x/c = 0.24$ and 0.07, respectively (see legend of Fig. 1 for definitions), whilst that on the under surface remained unaltered at about $x/c = 0.16$; the points on the upper surface were fixed by attaching wires of about 0.01 in. diameter transversely on the surface. To obtain the two more forward points for the wing of thickness ratio 0.30, the points of transition on both the upper and under surfaces were fixed by sticking thin paper sheets to the surfaces with their front edges in appropriate positions for which x/c was the same for both surfaces. For all the other points in Fig. 1., transition occurred spontaneously on surfaces which had been carefully smoothed and polished. The point corresponding to spontaneous transition for the wing of thickness ratio 0.10 has not been plotted because it lies very close to the more rearward of the two points for which transition was controlled.

The continuous curves in Fig. 1 are from computations made with certain simplifying assumptions. That for which t/c is zero relates to an ideally smooth thin flat plate and is built up from the Blasius solution for the laminar layer and the Prandtl-Kármán logarithmic curve for the friction of the turbulent layer, the change from laminar to turbulent flow being assumed to occur suddenly and without change of momentum loss. The two continuous curves for which t/c is 0.14 and 0.25, respectively, are from calculations made at Farnborough by H. B. Squire and A. D. Young. In these the skin friction of the laminar layer was calculated step-by-step along the wing profile, using Polhausen's approximate method of representing the velocity cross-sections by fourth power polynomials; the friction of the turbulent part of the layer was computed by a similar process on the assumption that the velocity cross-section of the layer retains a constant form.[1] Here also transition was assumed to occur suddenly without change of momentum loss. The drag coefficients shown by these curves are greater than the resultants of the skin friction forces, because they contain some "form drag" which can be shown to be an inevitable consequence of skin friction acting upon a wing of finite thickness.[2] The intermediate broken curves have been obtained by interpolation from the computed continuous curves and have been added merely to aid com-

[1] The "momentum thickness" was assumed to be 1.4 times the "displacement thickness." (See footnote 3.)

[2] By integrating von Kármán's momentum equation for the boundary layer, G. I. Taylor has shown that the drag of a thick wing must exceed the resultant of the skin friction forces by an amount which is calculable when the distribution of velocity is known in the boundary layer and in the wake as far back as the region of uniform pressure. H. B. Squire has shown how this additional term can be estimated approximately when only the

parison with the experimental points for wings of corresponding thickness ratio.

Though the basis on which Fig. 1 is constructed is not such as to allow fine points of difference to be examined, the figure suffices to illustrate clearly the three main conclusions of practical importance which can be drawn from the experiments to be discussed. These are: (1) That when the transition points are known the profile drags of smooth fair-shaped wings of moderate thickness can be computed with sufficient accuracy for most practical purposes from the known values of skin friction on a smooth flat plate. (2) That at moderate values of the wing Reynolds Number—five to ten millions—transition can be postponed to distances greater than 0.3 chords from the leading edge, with a consequent reduction of drag of the order 30 to 35 percent of the drag with the layer wholly turbulent. (3) That very small roughnesses or imperfections of surface are sufficient to move transition points forward and so increase drag.

In relation to the third conclusion it may be mentioned that, in one instance at Cambridge, when the wing Reynolds Number was about ten millions, a piece of tinfoil 0.002 in. thick, stuck down on the wing surface, appreciably influenced the position of transition. Again, at Farnborough, the drag of a smooth wing—measured by the pitot-traverse method—was appreciably increased when the aeroplane had flown through a cloud and this is considered to have been the result of a forward movement of the transition point, caused by mist drops deposited on the wing surface. Very small—barely perceptible—waves on the wing surface have also been shown materially to affect the point of transition and therefore the drag.

These considerations show the practical importance of knowing where upon the wings and other exposed surfaces of an aeroplane the boundary layer passes from the laminar to the turbulent flow, and they explain why the factors which influence the onset of turbulence are occupying the attention of many aeronautical research laboratories besides that at Cambridge.

Methods of Experiment

It is of course well known that the transition of the boundary layer from the laminar to the turbulent form is a gradual process, so that strictly one should speak of a transition region rather than of a transition point. The experiments of H. L. Dryden[3] and others have shown also that the transition region itself does not remain stationary, but is subject to rapid to-and-fro movements, so that in strict accuracy one cannot speak of a transition point without first defining it in relation to the mean position of a fluctuating transition region. In the experiments to be described, however, the effects of rapid fluctuations are automatically meaned by the slow response of the apparatus, and its indication of transition is sufficiently sharp to define a point on the wing surface which for practical purposes can conveniently be called the transition point.

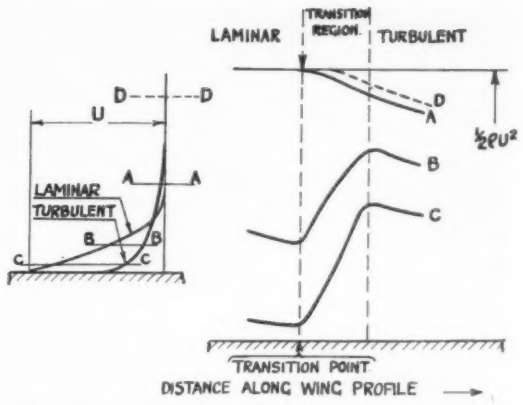


Fig. 2. **Diagrams for explaining the methods used for locating the region of transition to turbulent flow.** The left-hand diagram shows typical distributions of mean velocity in the boundary layer just before and just after the onset of turbulence. The right-hand diagram shows the variation of pressure in a pitot tube moved through the transition region along lines parallel to the wing surface at various distances from it.

The hot wire anemometer which has been widely used for the study of transition in the laboratory is not a convenient instrument for use in flight, and an alternative method involving very small pitot tubes has therefore been developed. This method depends on the changes which occur during transition in the mean velocity cross-section of the boundary layer. Typical velocity cross-sections just before and just after transition are shown in the left-hand diagram of Fig. 2, whilst the right-hand diagram of that figure shows, in sketch form, the changes which would occur in the pressure registered by a very small pitot tube moved through the transition region along lines lying parallel to the wing surface, such as *AA*, *BB*, etc. in the left-hand diagram. It can be seen from this figure that a small pitot tube moved in the direction of flow at a constant distance from the wing surface, along a line such as *AA* which just before transition lies just outside the laminar layer, will register, as indicated by line *A* of the right-hand diagram, a small fall of pressure as it passes into the thicker turbulent layer. Pitot tubes moved in a similar manner along lines, such as *BB* or *CC*, situated closer to the wing surface will, on the other hand, register a *rise* of pressure as they pass through the transition region. The distance along the wing surface within which these changes of mean pres-

distribution of skin friction on the wing surface is known. At the time of writing, these papers have not been published and are still under discussion. In the present instance the magnitude of this computed form drag for the wing of thickness ratio 0.30 is of the order 35 percent of the resultant of the skin friction forces. For the thinner wings the form drag is a smaller proportion of this resultant. (See reference 7.)

[3] Dryden, H. L., *Air Flow in the Boundary Layer near a Plate*, N.A.C.A. Report 562, 1936.

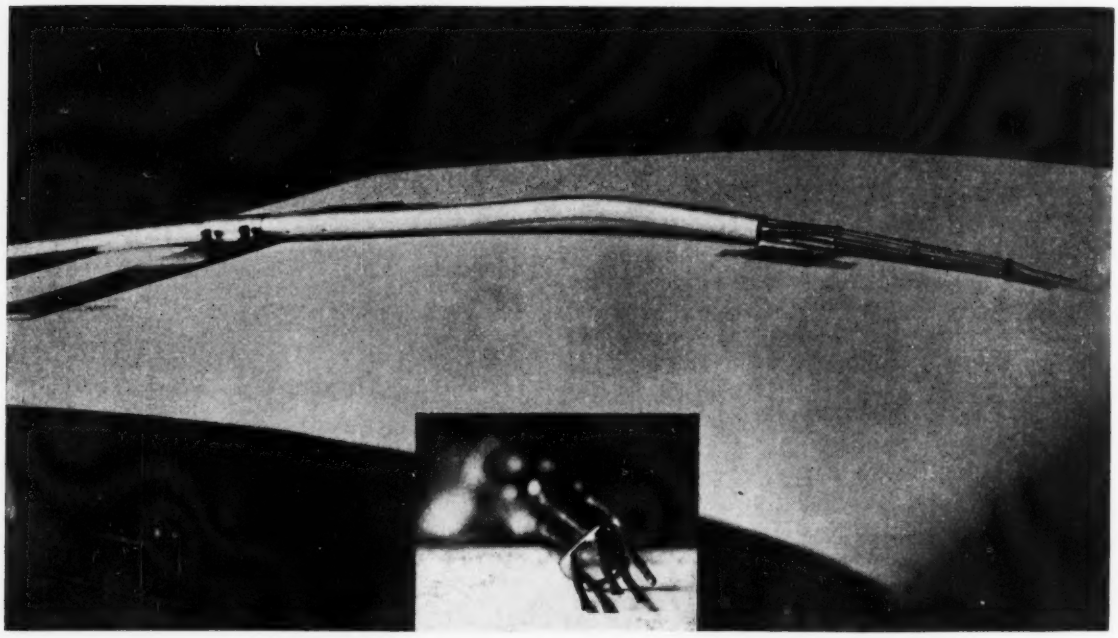


Fig. 3. Photographs of the five-tube head used for exploring the transition region in flight. The four tubes with orifices in the form of horizontal slits register total pressure at various distances from the wing surface, their outside dimensions at the front end are 0.012 in. deep and 0.064 in. wide. The tube with round closed end registers static-pressure.

sure occur varies of course with circumstances, but in the experiments to be described it was generally of the order four inches.

The phenomena described above can obviously be used to detect transition. In wind tunnel experiments it is generally more convenient to use pitot tubes close to the wing surface, in which pressure rises as the pitot passes into the turbulent part of the layer, for this method gives, when the external stream is smooth, a very precise indication of the first onset of turbulence and, since the exploring pitot can be placed in actual contact with the solid surface, it is not necessary to make any but a rough estimate of the thickness of the laminar layer before beginning the experiment.

In flight experiments, on the other hand, it is generally more convenient to use a pitot tube which lies altogether outside the laminar layer and in which pressure falls as it moves into the turbulent layer. There are two reasons for this: one is that, in straight flight at altitudes where the air is steady, total-pressure is very accurately the same at all parts of the potential stream, so that an exploring pitot, coupled through a manometer to another pitot conveniently situated anywhere in the potential stream, enables minute defects in total-pressure to be easily detected: the other is that the bore of the outside pitot tube can be made much larger than that of the inside pitot. The latter is a great advantage in flight experiments because a small pitot-tube implies a large lag in the response of the manometer to pressure changes and a possibility of error due to change of pressure and temperature consequent upon an accidental or deliberate change of height. This latter consideration is not so important in laboratory experiments where the capacity of the connecting tubes can be kept small and the external pressure and temperature can be maintained more nearly constant.

At first sight it might be supposed that the method of the outside pitot suffers from the severe disadvantage that the thickness of the laminar layer must be accurately known before the experiment begins, but a rough consideration of the quantities involved is sufficient to show that this is not so, unless very great accuracy in location of the transition point is required. The slope relative to the wing surface, of the effective outside boundary of the layer in the transition region is of the order $^1/_{25}$, so that a displacement of the outside pitot away from the wing surface by as much as 0.1 in. will shift the point where total-pressure loss is first detected by no more than 2.5 in. The effective thickness of the laminar layer just before transition upon a smooth wing at ordinary flight speeds is seldom much greater than 0.05 in. so that no great percentage accuracy in the estimation of its thickness is necessary in order to adjust the distance of the outside pitot from the wing surface so that it always lies outside the laminar layer, without being so far away from it as to make the position of the transition point uncertain by more than 1 or 2 inches. For example, the pressure variations in a pitot moved along *DD* in Fig. 2 would be roughly as indicated by the broken curve *D* in the right-hand diagram, and the corresponding shift in the supposed position of the transition point would be no more than some 2 in. It is apparent from this consideration

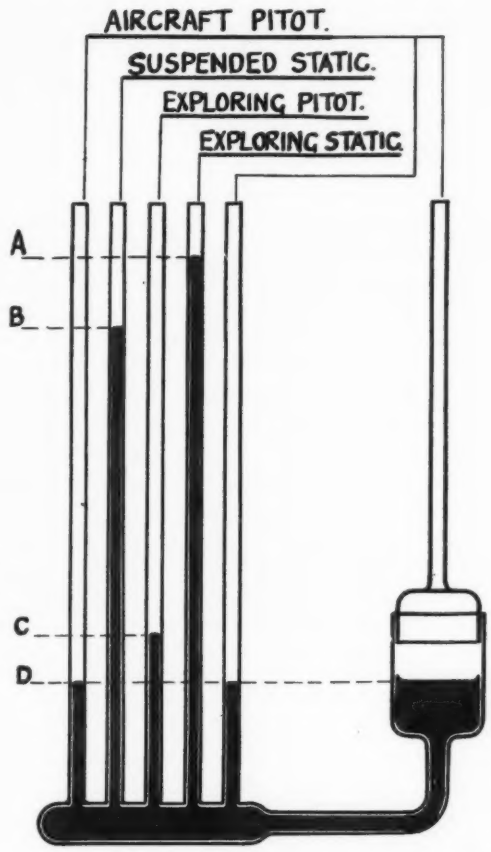


Fig. 4. **Diagram illustrating manometer connection.** The "impact pressure" of the aeroplane's airspeed is indicated by the distance BD, the total-pressure loss at the exploring pitot tube by the distance CD and the pressure (below atmospheric) at the exploring static-pressure tube by the distance AB. When the total-pressure loss and static-pressure are expressed in coefficient form by dividing by the impact-pressure the values obtained are obviously independent of aeroplane tilt or acceleration and of air or liquid density. The liquid generally used in the tubes is alcohol, but there are various heavy liquids of specific gravity up to 2.5 which can be conveniently used when the flight speed is very high.

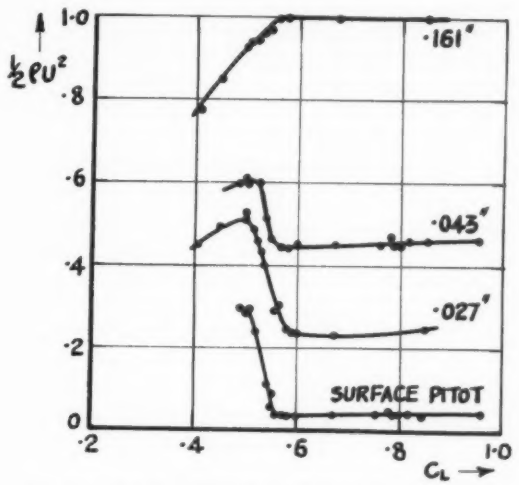


Fig. 5. **Typical observations of total pressure in the transition region.** These observations are from the four slit-ended pitot tubes illustrated in Fig. 3, which were situated on the under surface of the wing of thickness ratio 0.18 at 0.37 chords from the leading edge. The numbers written on each curve show the distance of the middle of the slit shaped orifices from the wing surface. Ordinates represent the total pressure registered by the tubes and abscissae the lift coefficient of the whole aeroplane. As lift coefficient increased the transition point moved backwards on the wing past the orifices of the tubes.

why much larger pitot tubes can be used by the outside method than by the inside method.

The most recent form taken by the pressure heads used in flight experiments at Cambridge is shown in Fig. 3. Here five tubes are used, each of 0.042 in. external diameter. One of these is a static-pressure tube by means of which the pressure distribution along the wing profile can be recorded.[4] The other four are pitot tubes with flattened orifices of external depth (perpendicular to the wing surface) of 0.012 in. and width 0.064 in. One of these tubes, known as the surface pitot, is in actual contact with the wing surface, whilst the other three are situated at various distances from the wing surface, such that two lie within the laminar layer and the third lies outside it. A convenient method of using this group of tubes is to fix them in some chosen position on the wing and record the pressures in them when the aeroplane is flown at various steady speds. The change of incidence and of Reynolds Number consequent upon change of flight speed cause the transition region to move along the wing profile and, if the position occupied by the tubes lies within the travel of the region, the conditions under which it passes them can be determined.

The manometer used in these experiments was of the multiple "U" tube type illustrated diagrammatically in Fig. 4. The tubes contain alcohol and records were made of the shadow of the meniscus thrown upon a sensitized paper close behind the tubes. This manometer enabled pressure differences to be measured to within about 1 percent of the impact pressure at the lower flight speeds and of course with greater accuracy at greater speeds.

A typical record from this instrument is shown plotted on a lift coefficient base in Fig. 5. In this instance the transition point moved backwards on the wing with increase of lift coefficient, so that the right-hand side of the figure relates to a laminar boundary layer and the transition point coincided with the orifices of the tubes at lift coefficient 0.55. Judging from the rate of movement of the transition point with change of lift coefficient, estimated from this and similar experiments with the tubes fixed in different positions on the wing, the transition region illustrated in this figure occupied about 4 inches of the wing profile.

[4] If necessary the small correction for pressure gradient normal to the wing surface is easily estimated and applied.

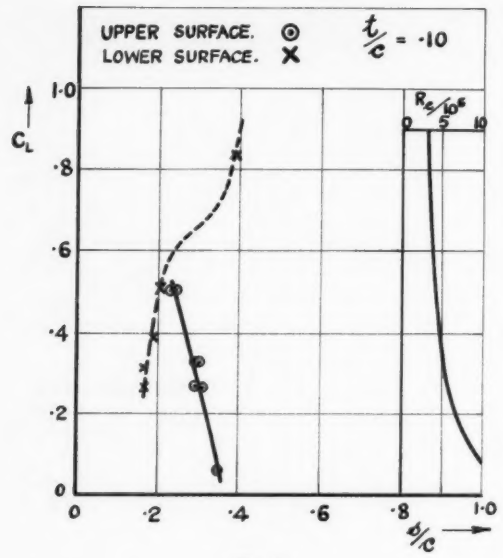


Fig. 6

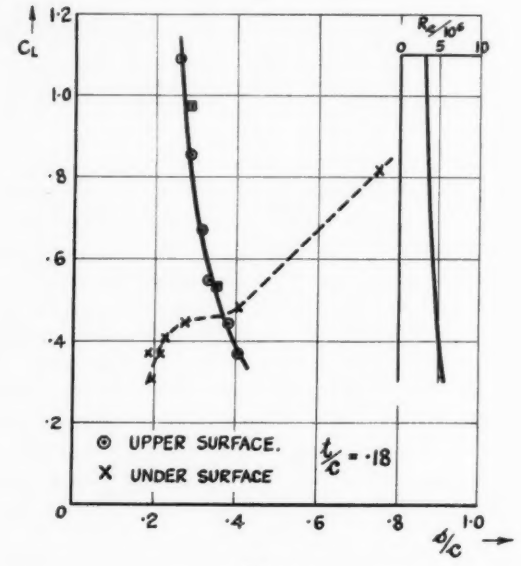


Fig. 7

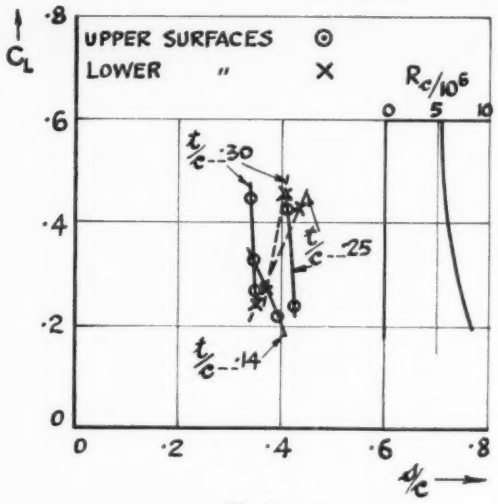


Fig. 8

Figs. 6, 7, 8. **Observations of the points of transition in the boundary layer of smooth wings in flight.** Ordinates represent the lift coefficient for the whole aeroplane; abscissae the ratio to the wing chord c of distance s—measured round the wing profile—between the front stagnation point and the point where turbulence first begins. The thickness ratio t/c of the wing profiles is shown in each figure. The approximate Reynolds Number R_c of the wing at each value of the lift coefficient is shown by a curve on the right-hand side of the figures. Figs. 6 and 7 are from experiments at Cambridge and Fig. 8 from experiments at Farnborough.

The rather complicated arrangement of five tubes described above was devised to enable the form of the laminar layer just before transition and the character of the transition region itself to be investigated; but when no more is required than to determine approximately the point where turbulence begins, much simpler arrangements can be used. In the earliest flight experiments on this subject at Cambridge a single pitot tube only was used, with circular end about 0.05 in. external diameter. This was stuck on to the wing surface with adhesive tape and the front bent up slightly so that the orifice lay just outside the estimated thickness of the laminar layer. In this simple way it is easy to find the position of the transition point on a wing within about a couple of inches, but unless the position of the tube can be altered in flight or the position of the transition region is roughly known beforehand, two or three flights may be necessary.

A refinement is to provide a second pitot tube and manometer and to place this second tube about twice as far from the wing surface as the first. This enables the slope of the outer boundary of the layer to be roughly determined and, since in the transition region this slope is some ten to twenty times as great as that of the laminar layer just before transition, all doubt as to whether transition has really occurred can be removed. After a little experience this refinement becomes unnecessary because, in the transition region, the characteristic shape of the curve of total pressure against distance along the wing is easily distinguished from the shape which results when the pitot merely enters gradually into the thickening laminar layer.

By such simple devices transition points could, if desired, be quickly and easily determined in testing organisations such as those of manufacturing firms, where the object is rather to ascertain what happens to specific aeroplanes than—as in research organisations—to investigate the general character of new phenomena.

The majority of the experimental results which will shortly be discussed were obtained with apparatus of complication intermediate between the five-tube arrangement illustrated in Fig. 3 and the single fixed pitot tube mentioned above. At Cambridge, for example, the greater part of the work has been done with a three-tube instrument, of which one tube was in the form of a static-pressure tube whilst the other two were

circular-ended pitot tubes both situated outside the laminar layer. These three tubes were rigidly connected together so that their working ends formed a small triangle and the whole was mounted on the wing in such a way that the tubes could be pushed by a small electric motor forwards and backwards along the wing profile, the object of the movement being to allow a larger number of observations to be made in a single flight. At Farnborough a somewhat similar arrangement of four tubes—one static-pressure and three pitot—has been extensively employed.

Results of Experiments

The experimental observations which are now to be considered were obtained in flight upon portions of wings of which the surfaces were carefully smoothed and polished. The coverings in some cases were considerably thicker than is usual in present practice, the object being to eliminate as far as possible the slight waviness which is often observed on wing surfaces and is the cause of local variations in the pressure gradients along the profile. Even so, the makers did not always succeed in eliminating every trace of surface waves, the effect of which on the observations were exceedingly interesting. The observations have all been made along profiles which lay between the body and inner ends of the ailerons, sufficiently far from either it is thought to avoid interference from those parts or from the airscrew slipstream.

The available information relating to the point of onset of turbulence on wings in flight is displayed in Figs. 6, 7, and 8, in which ordinates represent the lift coefficient of the aeroplane as a whole, and abscissae the distance of the transition point—measured round the wing profile—from the front stagnation point.

Fig. 6 shows the results of the first British experiments of this kind, which were made at Cambridge early in the present year upon the lower wing of a military biplane known as the Hart, the chord of which was 5 ft. in length. The approximate value of the wing Reynolds Number appropriate to each lift coefficient is shown at the right-hand side of the figure.[5] All the observations but one were made in level flight, with indicated flight speeds ranging from 60 to 126 m.p.h., at heights—round about 10,000 ft.—where the air was sufficiently calm to allow accurate observation. The exception is the point at lift coefficient 0.06; this point was obtained from observations made in long steep dives at an indicated air-speed of 240 m.p.h. The figure is built up from observations made in many different flights extending over several months.

On the upper surface of the wing the position of the transition point at each lift coefficient seemed to be very definitely established, but on the under surface, at lift coefficients round about 0.65, consistent results were more difficult to obtain, the position of the transition point being apparently very sensitive to air speed. A similar sensitivity at a different lift coefficient had been observed in some preliminary experiments made by very simple methods upon the same wing while it still had a standard fabric covering. Fig. 6 shows that at low lift coefficients the transition point on the under surface was much further forward than on the upper surface, but that as the lift coefficient increased the point on the under surface moved backwards whilst that on the upper surface moved forward.

Fig. 7 shows similar results obtained at Cambridge for a thicker wing of a small monoplane. In the place where the experiments were made the chord of this wing was 6.2 ft. in length; the maximum level speed of this aeroplane was, however, lower than that of the Hart, so that the Reynolds Number realised in level flight was about the same. These experiments, like those on the Hart, involved many flights on different days. The two points shown by squares in the group relating to the upper surface of the wing came, in fact, from check experiments made six months after the experiments which gave the other points in the figure had been completed. As with the Hart, the upper surface points were relatively easy to obtain, whilst on the under surface there was a range of lift coefficients in this instance round about 0.45, within which the position of the point of transition moved rapidly with change of lift coefficient, and seemed sensitive to surrounding conditions. As with the Hart wing also, transition occurred relatively far forward on the under surface at small lift coefficients, and the point moved backwards on the under surface and forwards on the upper surface as lift coefficient increased.

An interesting feature of this and the previous figure is the accuracy with which the observation points fall upon definite curves, despite the fact that they were obtained from experiments on many different days; to the observers it seemed almost as though they were locating points actually fixed upon the wings. This surprising consistency suggests strongly that, in these experiments at least, the cause of transition is to be sought in the system of flow set up by the aeroplane itself[6] and not in disturbances pre-existing in the atmosphere through which it flies; for it is unlikely that the nature and amount of atmospheric turbulence would remain exactly the same from day to day and from place to place. This deduction from flight experiment, if correct, is important, because wind tunnel experiments, upon which we have hitherto had to rely have

[5] At any given lift coefficient this number varies slightly in accordance with the load carried by the aeroplane, and with the temperature and density of the air, but these variations are small and would generally be included within the thickness of the curve.

[6] A conceivable cause of transition might be vibration due to engine or airscrew, but this is rendered improbable by observations—not here shown—which indicated that throttling the engine had little if any effect upon the position of the point of transition.

shown transition to be strongly influenced by turbulence of the tunnel stream. Some years ago G. I. Taylor[7] suggested that the rate of energy dissipation per unit volume of the atmosphere is too small for small scale turbulence of the kind which is known to influence boundary layer transition in wind tunnel experiments to be maintained, and it now seems probable, though not yet certain, that the atmosphere must from the present point of view be regarded as free from turbulence.

Fig. 8 shows the results of similar experiments at the Royal Aircraft Establishment, Farnborough, upon the wings of a small monoplane which was designed so that it could be reconstructed with wings of various thicknesses. The thickness/chord ratios of the wings examined were 0.14, 0.25, and 0.30, respectively. The two thinner wings were of conventional design tapering slightly from root to tip, but the profile of thickness ratio 0.30 was obtained by fitting a bulge on the 0.25 wing, which extended for about the half of one chord on each side of the measurement section. Previous wind tunnel experiments had shown that the boundary layer on a bulge of this kind is not seriously influenced by rapid changes of wing thickness on the sides of the bulge, but this matter is still under investigation. The main interest of these experiments lies in the fact that although the Reynolds Number reached in level flight was appreciably higher than that in the Cambridge experiments the transition points were even further back on the wing and the marked forward movement, observed in the Cambridge experiments at low lift coefficients, did not occur, though there was still a slight tendency for the point to move forward on the under surface and backward on the upper surface as lift increased. It is not yet known whether the absence in the Farnborough experiments of this marked forward movement on the under surface was due to a better technique in laying on the wing covering or to a difference in the designed form of the wing profile; there is, as will be seen, some evidence of slight imperfections in the shape of the under surfaces of the Cambridge wings, although the surfaces were always well smoothed and highly polished. It is worth noting that Stüper[8] in his experiments on the boundary layer of a wing in flight found transition points on the under surfaces in forward positions similar to those observed at Cambridge.

This, then, is the experimental evidence so far available in England upon the position of the point where turbulence begins in the boundary layer of smooth wings in flight. It shows conclusively that it is possible to retain a laminar layer over at least one-third of the whole wing surface, even when the Reynolds Number is as high as eight millions. Experiments are now being made at Farnborough to carry observations of this kind up to larger Reynolds Numbers, but conclusive results are not to hand at the time of writing. Drag experiments which have been already made at high Reynolds Numbers by the pitot-traverse method suggest, however, that though the points of transition may move forward somewhat at the higher numbers, they certainly do not move right forward to the leading edge and the laminar form of the boundary layer can still be retained over a considerable proportion of the wing surface.

It remains to consider in rather more detail the circumstances in which transition occurred in the experiments which have been described, in order to see whether any light can be thrown upon the factors which influence it, but before this can be done it is necessary to give brief attention to some of the well known conclusions which can be drawn from a consideration of the dimensions of the quantities involved.

Theoretical Consideration

If the boundary layer is thin enough for Prandtl's well known approximation to the equations of motion to be applied, then it is easily shown that the shape of the velocity cross-section of the laminar layer at any given position on a wing of given shape at given incidence, is independent of the size of the wing, the speed of flight and the density and viscosity of the air. If δ be a linear dimension defining the thickness of the layer, then it can also be shown that

$$R_\delta^2 \propto R_c$$

where R_δ stands for $\delta\ U/\nu$ and R_c for $c\ U_0/\nu$ in which U_0 is the velocity relative to the wing of the undisturbed air at a great distance, U is the velocity of the air just outside the boundary layer, c is the wing chord, and ν the kinematic viscosity of the air.

In analysing experimental observations it is convenient to choose for the linear quantity δ the value known as the "displacement thickness" and to represent it by the symbol δ_* which is defined as follows:

$$\delta_* = \frac{1}{U}\int_0^\infty (U - u)dy$$

where u stands for velocity within the layer at a point distant y from the wing surface.

For a flat plate in a flow field of uniform pressure, any of the well known mathematical solutions of Prandtl's approximate equations for motion within the laminar boundary layer give a relation which is very closely represented by

$$^1/_3\ R^2_{\delta_*} = R_x$$

where R_x stands for xu/ν, in which x is distance from the leading edge.

The expression $(^1/_3)R^2_{\delta_*}$ therefore provides a convenient dimensionless quantity, or number, by which

[7] Taylor, G. I., *Notes on Turbulence*, British A.R.C. type report No. 1502, 1934. (Unpublished.)

[8] Stüper, J., *Untersuchung von Reibungsschichten am fliegenden Flugzeug*, Luftfahrtforschung, Band 11, Nr. 1., 1934.

to define the thickness of the laminar layer at any position on a wing, for it has the properties that it varies directly with the wing Reynolds Number (R_c) and is, for the flat plate, equal to the familiar x Reynolds Number, by reference to which the already considerable amount of experimental data on transition is generally recorded. For brevity, this expression will be described as the *thickness number* and will be represented by the symbol N, so that

$$N = {}^1/_3 R^2_{\delta_*}$$

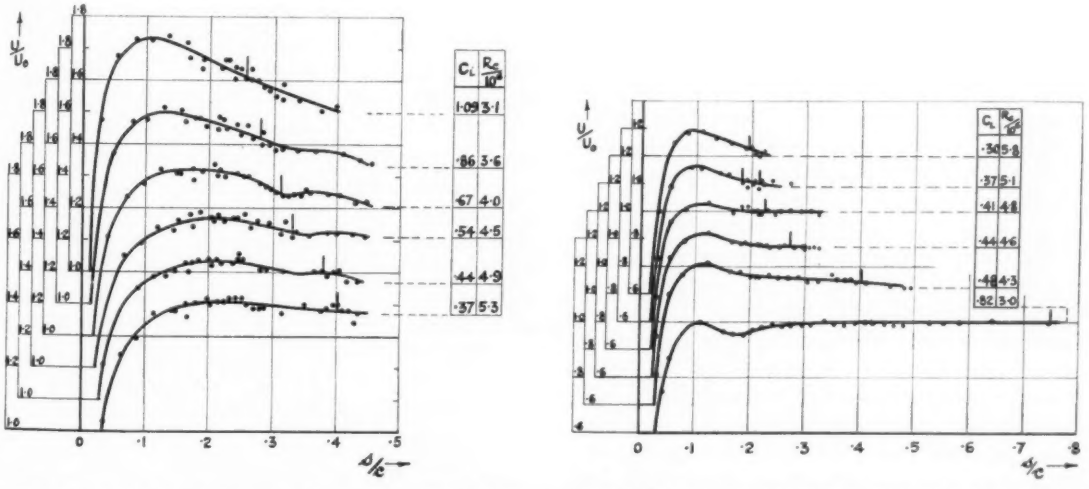
In considering the factors which may influence transition, the natural reaction of the investigator is to examine first whether they can be defined in relation to the local conditions within and immediately surrounding the layer near the transition point. The extreme thinness of the layer in comparison with the size of the wing suggests that this may be so, and if it is so, and if it is unnecessary to take into account time fluctuations of the quantities concerned, then consideration of the dimensions of the quantities involved suggests that transition should depend upon three parameters, N, λ, and C, of which N has already been defined, λ stands for[9] $(\delta^2/\nu)(p'/\rho U)$, where p is the pressure gradient just outside the layer in the direction of flow and C stands for the ratio of δ_* to the radius of curvature of the wing surface in a plane parallel to the direction of flow.[10]

It does not follow from these considerations that transition must depend solely, or even primarily, upon the three dimensionless parameters N, λ, and C; in fact the weight of evidence is, as will be seen, against this. The dimensionless analysis does no more than show that if, as seems at first sight probable, the phenomenon under consideration depends only on the variables from which the parameters are constructed, then it must be possible to express the conditions under which it occurs as functions of the parameters.

It is not impossible, of course, that the conditions which govern the onset of turbulence may include other factors, such for example as something which has occurred during the passage of the air from the front stagnation point to the point of transition, or even conceivably something which would happen in the laminar layer if it continued beyond the point where transition occurs in steady flight. It is conceivable that transition may occur first in some part of the boundary layer much further back on the wing and that the turbulence then runs forward under the influence of the pressure gradients set up locally in the potential flow by the rapid increase of boundary layer thickness which accompanies transition. Again, it must be remembered that the quantities which have so far been measured in flight are time-means only, of quantities which may have been fluctuating and it is therefore possible that the primary cause of transition may ultimately be associated with fluctuations which have not been recorded in the flight experiments.

[9] In order to conform with what is now a standard convention, the quantity δ used in the definition of λ is the full boundary layer thickness as defined in Polhausen's polynomial representation of the velocity cross-section. Since with Polhausen's approximation δ is a function of δ_* this procedure involves no loss of generality.

[10] Curvature in a plane perpendicular to flow direction may conceivably influence transition, but with wings this curvature is probably too small to be of any importance.



Figs. 9 and 10. **Specimen curves from observations of pressure distribution measured in flight.** Ordinates show ratios of the speed U relative to the wing of the air just outside the boundary layer to the speed U_0 of the air at a great distance from the wing, the values being obtained by means of the Bernoulli Theorem from measurements of pressure made with a small travelling static-pressure tube similar to that illustrated in Fig. 3. Abscissae represent the ratio to the wing chord c of distance s, measured round the wing profile, from the stagnation point to the observation point. The curves are fair curves drawn through the observation points and the short vertical marks upon them show where turbulence was observed to begin.

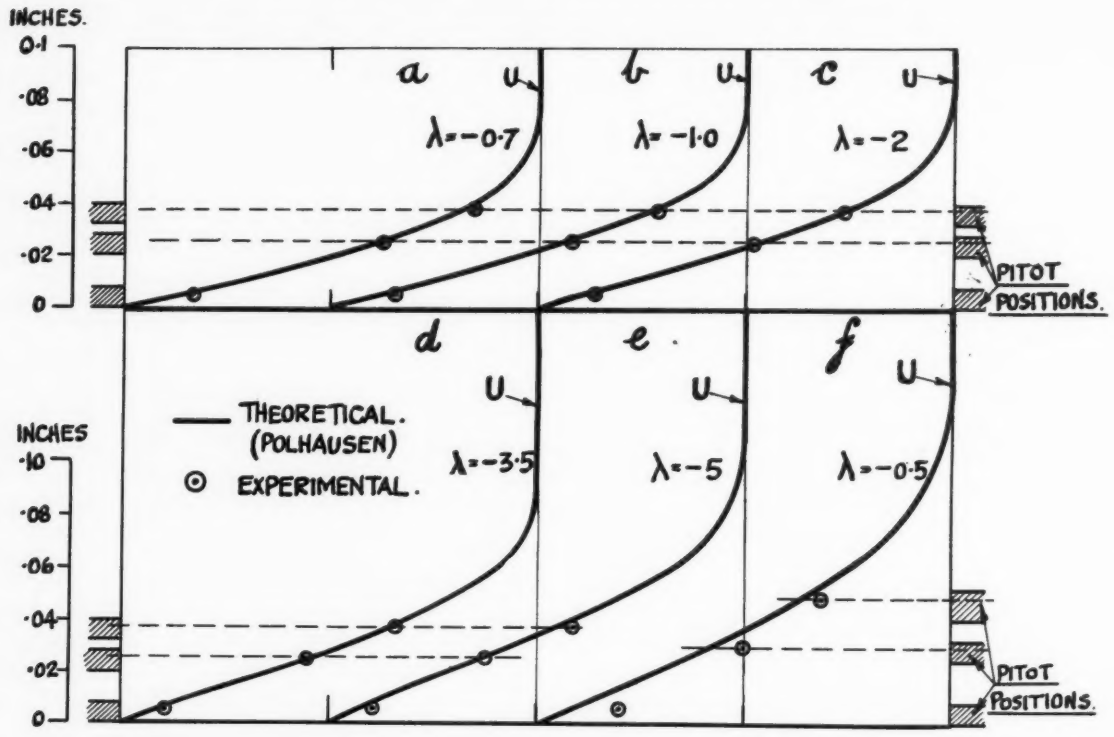


Fig. 11. **Comparison between computed and observed velocity cross-sections of the laminar boundary layer.** Ordinates represent distance from the wing surface and abscissae air velocity expressed as a fraction of the velocity outside the layer. The curves are computed by Polhausen's method and the points are from flight experiments with pitot tubes whose positions and depths are shown at the sides of the figure. The effective centres of the two outer pitots are taken as on the broken lines which are displaced from the geometrical centres by distances equal to 0.2 times the external depth of the flattened ends of the tubes, in accordance with the conclusions in footnote 11. The effective centres of the pitots in contact with the wing surface are estimated from information in footnote 12.

Consideration of the Factors Which May Control Transition

In order to examine whether the factors which control the transition from laminar to turbulent flow in the boundary layer can be simply expressed in terms of the three dimensionless parameters, N, λ, C, of the previous section, the values of these parameters have been estimated by step-by-step computation, starting from the front stagnation point and working backwards along the wing profiles to the observed transition points. In these computations the velocity U in the potential flow just outside the boundary layer and the pressure gradient p' along the profile were obtained from curves based on pressures actually registered in flight by the small static-pressure tubes previously described. Graphs, based on a typical series of such observations of pressure, are reproduced in Figs. 9 and 10 to show the order of accuracy attained in the experiment. The quantity actually plotted in these figures is not the pressure itself, but the velocity U just outside the boundary layer which can, of course, be deduced from the pressure by using the Bernoulli Theorem.

The computations of the values of the parameters were made by Polhausen's method in which velocity cross-sections of the boundary layer are represented as polynomials of the fourth order. This method is approximate only, and doubt has been expressed as to its accuracy when applied in circumstances where the parameter λ is negative. Some experimental check was therefore required to determine whether the method gives sufficiently accurate information in the circumstances in which it has been applied. For this purpose a very careful set of observations were made in flight with the five-tube arrangement illustrated in Fig. 3. These tubes were fastened at a fixed position on the surface of the wing of thickness ratio 0.18 and the pressures registered by them were recorded when flying steadily with various values of the lift coefficient. The velocity cross-sections of the boundary layer at the orifices of the tubes were then computed from pressure distributions obtained in previous experiments.

A comparison between computed and observed values is shown in Fig. 11 (a) to (f), in which (a) to (e) relate to a position on the upper surface of the wing, 20 in. behind the stagnation point, measured along the sur-

[11] Young, A. D., and Maas, J. N., *The Behaviour of a Pitot Tube in a Transverse Total-Pressure Gradient*, British A.R.C., R. &. M. 1770, 1937.

[12] Fage, A., and Falkner, V. M., *An Experimental Determination of the Intensity of Friction on the Surface of an Aerofoil*, British A.R.C., R. & M. 1315, 1930.

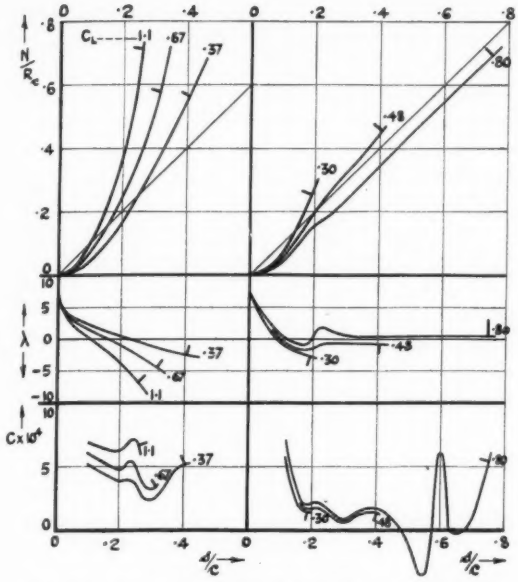


Fig. 12. **Examples of the distribution of certain dimensionless quantities which define local conditions in the laminar boundary layer.** The thickness/chord ratio of the wing to which these curves relate was 0.18. Lift coefficients are written against the curves, and the observed points of transition are shown by short cross lines on each curve. Abscissae represent ratios to the wing chord c of distance s, measured along the wing profile from the front stagnation point. Of the other symbols, N defines the layer thickness, λ the pressure gradient within the layer, and C the curvature of the wing profile; they are more precisely defined in the text. Negative values of λ correspond to rising pressure gradients and separation of flow from the wing surface is generally assumed to occur when $\lambda = -12$.

face, whilst (f) relates to a position on the under surface 26.5 in. behind the stagnation point. The remarkably close agreement shown in Figs. (a) to (e) may be to some extent accidental, for it is not considered that the distances of the pitot tubes from the wing surface were known with certainty to an accuracy greater than about 0.004 in.,[13] but the experiment shows that, in this instance, Polhausen's method gave δ_* values which agreed with the observed values within, say, 10 percent, even when the negative values of λ were as great numerically as five.

It is of some interest to consider the variation of the computed values of the parameters N, λ, and C at different positions along the wing profile, between the forward stagnation point and the point of transition and a few typical curves illustrating these distributions are therefore reproduced in Fig. 12. In this figure the parameter N is defined, not by its actual value, which varies with the wing's Reynolds Number R_c, but by the ratio N/R_c, which, for any given position on a wing of given shape at given lift coefficient, is a constant independent of R_c. For a flat plate in a uniform pressure field, N is, as has been seen, equal to R_s where s is the distance from the leading edge, hence the variation of N/R_c with s/c for a flat plate is represented in Fig. 12 by a straight line inclined at 45°.

The radius of curvature of the wing surface which is involved in the parameter C was obtained by an instrument of which two points, 6 in. apart, were pressed lightly on the surface, whilst a third, midway between them, actuated a micrometer dial. The measured radii were, therefore, mean values over 6 in. of the profile.

The curves in Fig. 12 are of some general interest, because they are fairly well typical of any wing of moderate thickness and conventional profile. Such curves can, of course, be obtained for any wing profile by computation alone, without experimental determination of the pressure distribution, since the latter can be obtained in the usual way from potential flow theory, but in the present instance it was thought preferable to employ the measured pressure distributions so as to include the effects of accidental variations of the actual wing profile from the designed profile.

The point where turbulence was observed to begin in the experiments from which the pressure distributions were obtained is marked on each curve and, where the curve is carried slightly beyond this point, the implication is that the laminar layer would have taken the computed form if turbulence had not, in fact, intervened. A difficulty of interpretation arises here on account of the characteristic kink which always occurs in the pressure distribution curves near the point of transition (see Figs. 9 and 10). In the present instance all quoted values of λ have been obtained from fair curves drawn through the points without regard to the kink, the reason for this procedure being that the kink is regarded as a *consequence* of transition itself, and the ultimate object of the research is to find how far it is possible to predict the point of transition from estimated information concerning the laminar layer in the absence of transition.

The N/R_c curves at the top of Fig. 12 show that near the front of a fairly thick wing the displacement thickness of the laminar layer at any given distance from the stagnation point is much less than it would be in corresponding circumstances at the same distance from the leading edge of a flat plate. They show, however, that as distance from the stagnation point increases the thickness of the layer begins to increase more rapidly than on a flat plate, until somewhere not far from the point of minimum pressure ($\lambda = 0$) the local Reynolds Number of the layer thickness catches up the flat plate values and eventually rises considerably above them. Only in one curve, that relating to the under surface at very large lift coefficients, does the displacement thickness remain always below the corresponding flat plate values.

The λ curves, half way down Fig. 12, all start at the front stagnation point of the wing from Polhausen's figure, -7.05, and fall rapidly as distance from the

[13] A subsequent series of measurements by the same observer to check the accuracy of the method by which he had measured these distances showed that his measurements were subject to an error whose "probable" value was 0.002 in.

TABLE 1

Data Relating to the Laminar Boundary Layer of Certain Wings, from Computations Based on Measured Pressure Distributions

			C_L	$R_c/10^6$	s/c	λ	$N/10^6$	$C \times 10^4$
CAMBRIDGE	$t/c = .10$	Upper Surface	.06	10.8	.35	±1.0	3.7	1
			.27	5.8	.32	−2.1	2.0	2
			.27	5.5	.30	−2.2	2.4	2
			.33	5.2	.30	−2.2	2.1	2
			.33	4.9	.30	−2.1	1.9	2
			.50	4.0	.23	−3.7	1.5	2
			.50	4.2	.25	−4.1	1.6	2
		Under	.27	5.2	.17	+0.1	0.8	1
			.32	4.8	.17	−0.4	0.8	1
			.38	4.4	.19	0.0	0.7	1
			.51	3.9	.21	+0.4	0.6	2
			.84		.40			
	$t/c = .18$	Upper	.37	5.3	.40	−2.2	3.0	5
			.44	4.9	.38	−2.5	2.8	5
			.54	4.5	.33	−3.5	2.4	4
			.67	4.0	.31	−4.6	2.3	4
			.85	3.6	.28	−5.2	2.2	5
			1.09	3.1	.26	−7.2	2.2	7
		Under	.30	5.8	.19	−4.4	1.6	1
			.37	5.8	.18	−3.1	1.1	1
			.37	5.1	.22	−4.2	1.5	1
			.41	4.8	.23	−2.1	1.2	1
			.44	4.6	.27	−0.8	1.3	1
			.48	4.3	.40	−1.0	1.9	1
			.82		.75	0.0	2.3	5
FARNBOROUGH	.14	Up.	.33	6.8	.35	−2.3	2.8	3
			.22	8.2	.40	−3.7	3.7	3
	.25	Up.	.43	5.7	.41	−6.9	4.3	5
			.24	7.7	.42	−5.3	4.8	4
		Un.	.43	5.7	.43	−4.9	3.4	4
			.24	7.7	.35	−3.1	3.3	3
	.30	Up.	.45	5.6	.34	−4.0	3.2	4
			.27	7.4	.35	−3.8	4.1	4
		Un.	.45	5.6	.40	−1.3	2.9	4
			.27	7.4	.37	−2.0	3.9	4

stagnation point increases. They pass, of course, through zero at the point of minimum pressure, and on the upper surfaces the negative values thenceforward increase numerically up to the point where turbulence begins. The values for the under surface at first fall off more rapidly than those of the upper surface and, after passing through zero, rapidly rise, sometimes crossing the zero line again before they eventually settle down to a value not far different from zero. It seems probable that the more violent bends in these under surface λ curves are to be attributed to some imperfection in the shape of the surface itself, and it is not improbable that they are in some way associated with the relatively early onset of turbulence observed on the under surface of this wing. Similar double bends associated with forward positions of the transition point were also noticeable in the corresponding curves—not here reproduced—for the under surface of the wing of 10 percent thickness/chord ratio.

The curves at the bottom of Fig. 12 show approximately the variations of the parameter C. The violent fluctuations of the curve for the under surface between lift coefficients 0.5 and 0.8 are due to an imperfection of the wing surface in the form of a barely perceptible wave. It is of some interest to observe that this violent fluctuation of the C curve did not immediately cause transition to the turbulent regime.

The computed values of the three parameters N, λ, and C, relating to the laminar boundary layer at points where transition to the turbulent form had been observed in flight, are collected together in Table 1, and the values of N given in this Table are plotted against the appropriate values of λ in Fig. 13. It appears from the Table and figure that the λ values at transition all lie, speaking broadly, between 0 and -7, but that within this range there appears to be no simple relation between the two parameters.

The situation is not appreciably clarified when the values of the curvature parameter C are taken into consideration, for although Table 1 shows that the very low values of N and λ observed on the under surfaces of the Cambridge wings are associated with low C values, the very high values of N and λ found at Farnborough are associated with lower C values than those of many of the Cambridge upper surface observations. Though the observations recorded in Table 1 do not preclude the hypothesis that surface curvature may have some influence on transition, they certainly show that in these experiments it did not exert the predominating influence.

One feature which stands out clearly in Fig. 13 is that the two series of points representing observations on the upper surfaces of the wings examined at Cambridge fall very closely upon definite curves, though the curve is not the same for both wings. This consistency of the points for each wing taken alone is, of course, a direct consequence of the close functional relations between the lift coefficient and the position of the transition

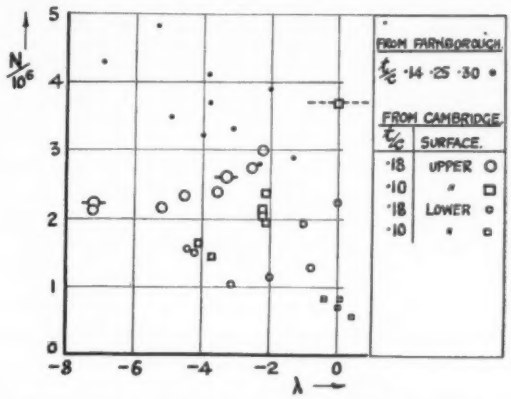


Fig. 13. **Values of N and λ at transition for a number of different wings in flight.** The parameters N and λ are defined in the text and further information relating to the circumstance in which each point was obtained is given in Table 1. The wide scatter of the points from different wings shows that these two parameters alone are insufficient to define the conditions which lead to transition in these experiments. The broken horizontal line through one of the small squares shows that in this instance the value of λ was not known with certainty within the limits shown by the line.

point which are revealed in Figs. 6 and 7; for, at any given point on a profile, both N and λ (as computed) are functions of lift coefficient. Bearing in mind the fact that the experiments in which these points were observed were made on many different days, sometimes with intervals of months intervening, it seems difficult to escape the conclusion already mentioned that the onset of turbulence was occurring under the influence of some dominating parameter whose origin is to be sought in the system of flow set up by the wings themselves. The wide scattering in Fig. 13 of the points for different wings shows, however, equally clearly that in these particular experiments the conditions leading to transition cannot be expressed simply in terms of the three parameters, N, λ, and C.

What the parameter which was controlling transition may be is still uncertain, but there are at the time of writing some indications from various sources as to its probable nature. It will be recalled that the apparatus used for observing the conditions of flow near the point of transition was of a kind which records time-means only of values which may in fact have been fluctuating. If therefore, keeping in mind the thinness of the laminar layer, we still retain the hypothesis that the onset of turbulence is determined by local conditions, we are almost forced to the conclusion that the unknown parameter is to be sought in some form of fluctuation superimposed upon the mean flow.

H. L. Dryden[3] using a hot wire anemometer within the laminar layer of a flat plate in a wind tunnel, has found just such fluctuations of surprisingly slow period and has published a figure which suggests strongly that in his experiments these fluctuations were in fact the primary cause of the ultimate break-down of the

laminar flow. L. Schiller[14] experimenting in similar circumstances has found similar fluctuations and has also shown that the point of transition can be controlled within a very wide range by slight alterations of the incidence of the flat plate, which caused relatively large displacements of the stagnation point on the rounded leading edge.

Working in collaboration with G. I. Taylor, we have recently constructed at Cambridge a small wind tunnel in which the working stream is remarkably free from turbulence, the root-mean-square of the longitudinal fluctuations of velocity being of the order of 0.1 percent of the mean speed, whilst that of the lateral fluctuations is about 0.2 percent of the mean speed. In this tunnel, using a flat glass plate $^3/_8$ in. thick with rounded leading edge, we have observed the same phenomena as were observed by Dryden and Schiller; that is to say, hot wire examination has shown that relatively long period fluctuations of velocity occur in the laminar layer without being apparent in the potential flow outside the layer, and that the point of transition can be powerfully and very definitely controlled by slight alterations of incidence.

Consideration of results such as these from our own and other laboratories suggests that the final transition of the boundary layer to the fully turbulent condition may be the direct consequence of transient separation of the flow from the solid surface, brought about by these relatively slow fluctuations, but no experiment of which we are aware has, as yet, revealed with any certainty the origin of the fluctuations themselves. Whether for example their origin is to be found in minute fluctuations of the external stream, which become greatly magnified within the layer, or whether it is to be sought in some property inherent in the boundary layer itself, is a question which has yet to be determined, though the similarity of the fluctuations observed in the smooth flow of our new tunnel to those observed by Dryden in a stream of greater turbulence, lends some support to the latter view.

In the unusually smooth stream of our new tunnel we find, as was to be expected, that transition can be postponed until the value of N is considerably greater than the values usually obtained in tunnels of greater turbulence. Our tunnel is not long enough to realise values of N much above three millions, but this value has been reached without transition to the turbulent regime and it seems probable that in longer equally smooth tunnels it will be exceeded, even when the value of λ at transition is zero or slightly negative.

By modifying the shape of the tunnel walls one can produce, within limits, any desired sequence of pressure gradients along the surface of the plate, and we find, by this means, that the value of N associated with any given value of λ at transition can be greatly altered by changing the gradients through which the air has passed on its way to the transition point. Thus, the introduction of a sharp falling pressure-gradient, followed by a rising gradient, causes transition to be postponed to larger N values than when the rise of pressure is continuous from near the leading edge, and in this way we have succeeded in realising N values greater than two million, even when the negative value of λ was as great as seven. These observations support the conclusion previously drawn from the flight experiments, that the conditions which lead to transition cannot be expressed solely in terms of the mean values of quantities in the immediate neighbourhood of the transition point itself.

The introduction of artificially generated turbulence into the smooth air stream is found to have the well known consequence of causing transition to occur earlier than in the smooth stream and to cause the mean transition point—as located by slow-reading pitot tubes—to become much less clearly defined; no doubt because the amplitude of the to-and-fro movement of the transition region is greatly increased. This explains the remarkable precision and definition of the majority of experiments for the location of the point of transition in flight, in comparison with the results of previous experiments in wind tunnels. We find also that phenomena, such as the delicate dependance of the point of transition on the incidence of a flat plate, become much less apparent and definite when the turbulence of the tunnel stream is increased. It is now, in fact, becoming apparent that the more interesting features of the phenomenon of transition have in the past been masked by wind tunnel turbulence, and that the extension of the experiments to free flight coupled with the greater smoothness of flow in modern wind tunnels is opening up new fields for investigation.

It is yet too early to hazard an opinion as to what will be the final outcome of experiments of the kind we have been discussing. Whether or not the stream of information which comes in almost daily from aeronautic laboratories in many countries will ultimately reveal the possibility of controlling transition so as still further to reduce drag, or whether it will merely enable the point of transition to be predicted without enabling it to be controlled is a question which awaits an answer. For my part I am not able even to guess what the answer will be, but knowing that the problem is being intensively studied in the United States, I have, with the consent of my colleagues in England, told you exactly what we are doing and where we are as yet uncertain, in the hope that the discussion to follow will bring to light complementary evidence which, combined with our own, will enable a clearer picture to be formed of a phenomenon in which theorists and engineers alike are intensely interested.

[14] Schiller, L., *Neue quantitative Versuche zur Turbulenzentstehung*, Z.A.M., Band 14, Heft 1, 1934.

Discussion

PROFESSOR JONES' paper was presented at the Pupin Physics Laboratories of Columbia University on the afternoon of December 17, as a lecture which gave the principal results of the research work up to the time Professor Jones left Cambridge University two weeks before.

There were about 300 members and guests of the Institute present including Orville Wright.

Dr. Nicholas Murray Butler, President of Columbia University, welcomed the guest speaker, Mr. Wright, and members of the Institute. He spoke of his early interest in aviation and of the interest of Columbia University in the growth of the Institute, as all of its Annual Technical Meetings had been held in the Pupin Physics Laboratories. He expressed the hope that the Institute would continue to find the facilities of Columbia University helpful in its work. He praised the work of the Wright brothers and spoke of the great aeronautical development which their work inaugurated.

Introduction

Dr. Clark B. Millikan
California Institute of Technology

As you all know we are today privileged to be present at what will, I am sure, be remembered as an historic occasion: the first Wright Brothers' Lecture. I shall not spend any time discussing the significance of the occasion since this will be done tonight. However, before introducing the speaker, I do wish to express our great appreciation to Columbia University, to Dr. Butler, and to Professor Pegram for their kindness in making this meeting place available and in welcoming us so warmly. Columbia saw the birth of the Institute, and all of our technical sessions have been held at it. It is, therefore, most happy for us that now the inaugural Wright Brothers' Lecture is held under its auspices. Thank you again Dr. Butler and Professor Pegram.

I have been fortunate in knowing today's speaker for over seven years. Unfortunately the chances for personal contact have been few, but I have been able to follow his work fairly closely.

All of his contributions seem to me to have been marked by certain definite characteristics: (1) an interest in scientific problems which are closely related to the actual flight of aircraft; (2) a penetrating analysis of the problems attacked so that the simple fundamentals appear out of a maze of apparent complications; and (3) extreme ingenuity in developing simple experimental methods for studying the problems.

All of these characteristics appear strikingly in the work which the speaker has chosen for his subject today.

B. C. Boulton
The Glenn L. Martin Company

In this significant paper Professor Jones does not tell us how to control the boundary layer and hence vastly increase airplane performance, but like a true scientist he records basic phenomena and does much to lay a sound foundation on which others can build. Most of us shy off when the subject of boundary layer is mentioned and feel that it is too abtruse for the engineer; that it must be left to the scientist and mathematician. The present paper, however, does much to remove this barrier and gives us all a concrete realization and at least partial understanding of the subject. I will leave to my able colleagues in this discussion the more difficult task of commenting on the theory involved and will limit myself to emphasizing some aspects of special significance to the engineer.

In Fig. 1 it is of importance to note that the slope of the curves of decreasing drag with aft movement of the transition point is greatest for thick airfoils. With larger wings of higher aspect ratio the thickness ratios used are higher. In such cases the gain to be derived by using all means of maintaining laminar flow is great; also the corresponding loss. It may be remarked that except for thickness ratios of .30 and .10, the slopes of the curves are determined mathematically rather than experimentally. Another point that is rather amazing is that the forward transition point in the case of $t/c = .3$ was produced by the use of a thin sheet of paper. In another case a sheet of foil .002 in. thick affected the transition point. The sacrifice involved in a lap joint becomes painfully evident. This brings home to us the truth of the N.A.C.A. tests on the effect of roughnesses shown at the last annual conference. The fact which Professor Jones brings out that slight waves in an otherwise smooth surface also materially affect the transition point especially interests me. In the interests of weight saving we may use thin gage material on a leading edge and feel, if the rivets are flushed, that all is right. If the material, because of its thinness, is wavy, all is not right, and on a long range aircraft the additional drag, so caused, may involve far more weight in fuel expenditure than that due to differences in gage. This is of significance structurally, and indicates we must count on the wing leading edge for structural strength since it must be reasonably heavy to secure low drag.

I believe it has been the general impression that as a wing becomes larger, little roughnesses due to skin laps and rivets become less important. Professor Jones points out the tendency with increasing Reynolds Number for the transition point to move forward, though also holding out the possibility that with care the drag of wings on very large airplanes can be greatly reduced by keeping part of the flow laminar instead of entirely turbulent as would usually be assumed.

Of particular interest is the statement, verified by the constancy of the flight test results, that small scale turbulence does not exist in the atmosphere, and so for exploration of the boundary layer, flight experiments are more reliable than wind-tunnel tests. Turbulence in the latter case tends to mask the phenomena being investigated. As Professor Jones suggests it may be possible for an airplane manufacturer, using a single pitot tube just outside the laminar boundary layer, to make valuable investigations on the effect of different wing finishes and types of rivets as part of normal flight testing.

I would like to ask Professor Jones whether work has been done or is planned shortly, on exploring the boundary layer on hulls or fuselages. Since such elements constitute such a large proportion of the airplane drag, such work might prove to be of great value.

In recent flight tests at our plant we obtained a great reduction in drag through the use of cowl flaps on a radial engine to throttle to a minimum the cooling air at high speed. Part of the gain was due to increased pumping efficiency but we would like to inquire whether Professor Jones believes that the high speed air from the narrow gill slot could have acted as a sort of boundary layer control, thus further reducing the drag.

Dr. Hugh L. Dryden
National Bureau of Standards

The Institute is greatly indebted to Professor Jones for his very clear presentation of the practical importance to the airplane designer of an understanding of the nature of the flow in boundary

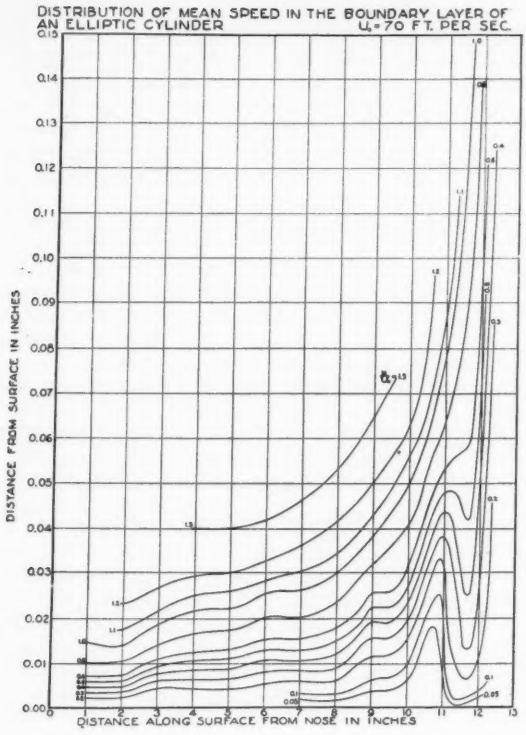

DISTRIBUTION OF MEAN SPEED IN THE BOUNDARY LAYER OF AN ELLIPTIC CYLINDER
U=70 FT. PER SEC.
DISTANCE FROM SURFACE IN INCHES
DISTANCE ALONG SURFACE FROM NOSE IN INCHES

FIG. 1.

layers and in particular of the factors controlling the transition from laminar to eddying flow. He and his colleagues honor us by making available in the Wright Brothers' Lecture information of fundamental importance not hitherto published. Research workers in this country do have some additional information to add to that of Professor Jones, but must join him in admitting that the problem has not been solved and it is not known whether it will ultimately be possible to control transition to reduce drag. The more data obtained, the more complicated appear the phenomena.

In the experiments described by Professor Jones, a number of factors operating together influence the position of the point of transition and make analysis exceedingly difficult. Thus the increase of Reynolds Number with decreasing lift coefficient tends to move the point of transition upstream, whereas the effect of the change in pressure distribution accompanying the decreasing lift coefficient may tend to move the point of transition downstream. It may therefore be possible to find some airplanes for which the point of transition is nearly stationary as the angle of attack is changed. The available theories are not adequate to describe the influence of the several factors and more experimental work is needed with conditions controlled to give but one variable factor at a time. Reynolds Numbers and turbulence conditions corresponding to those in flight can however be obtained only in flight or in a full-scale wind tunnel of low turbulence.

The National Advisory Committee for Aeronautics has sponsored and financed a coordinated program of research on this problem at various university laboratories, at the National Bureau of Standards and in its own laboratories. The California Institute of Technology is studying the influence of curvature and roughness on transition and a progress report has been made available in Technical Note 613 of the National Advisory Committee for Aeronautics. The Massachusetts Institute of Technology is studying the influence of pressure gradient and the National Bureau of Standards the influence of wind-tunnel turbulence. The Langley Field Memorial laboratory is investigating the phenomena at large Reynolds Numbers in the full-scale wind tunnel and in flight. By permission of Dr. G. W. Lewis, I am able to discuss the problem in the light of our work at the National Bureau of Standards, making use of some data not yet published by the Committee.

The use of a small number of total head tubes for determining transition is in general satisfactory and makes possible a fairly rapid accumulation of data. There is, however, a certain danger of missing an important phenomenon, namely, that of laminar or quasi-laminar separation, followed by a return of the flow to the surface, a phenomenon to which Professor Jones himself directed attention in his paper on *Stalling* in the Journal of the Royal Aeronautical Society, Vol. 38, p. 753, 1934. We have observed this phenomenon in recent experiments on the boundary layer near an elliptic cylinder.

The results of a detailed survey of the laminar boundary layer near this cylinder, in which laminar separation occurred, have been published. Comparison with theoretical calculations by Pohlhausen's method did not lend confidence in that method for computing separation, separation occurring for $\lambda = -5.4$ instead of Pohlhausen's value of -12. The theoretical speed distributions agreed fairly well with the observed distribution for values of the parameter λ between $+7$ and -5. Professor Jones' data in Fig. 11 are in agreement with this result. The limitations of Pohlhausen's method should, however, be clearly understood. The method developed by von Kármán and Millikan is much better although requiring more tedious computations. (See Millikan, Clark B, *A Theoretical Calculation of the Laminar Boundary Layer Around an Elliptic Cylinder, and Its Comparison With Experiment*, Journal of the Aeronautical Sciences, Vol. 3, No. 3, January, 1936.)

Our recent measurements at the National Bureau of Standards were on the same elliptic cylinder at a higher speed (70 ft. per sec.) where transition occurred before separation. A contour map of the speed distribution as obtained by hot-wire measurements is shown in Fig. 1. Between 10.2 and 10.8 inches from the nose a region of reversed flow can be demonstrated by the use of smoke, lampblack, and oil on the surface, or any similar method. Since the hot wire is essentially a non-directional instrument, the reversal is not shown in the hot-wire measurements. From 10.8 inches to the second separation at 12 inches, the flow near the surface is in the direction of the main stream. The diagram is based on traverses at stations along the cylinder spaced 1 inch apart. By a method described later it can be demonstrated that a minimum in the local skin-friction coefficient occurs at 6.1 inches from the nose, although the phenomenon is not evident in the figure. We may therefore picture transition beginning at 6.1 inches, sufficient turbulence being produced to carry the layer some distance against the rising pressure but insufficient to prevent separation altogether in the region of rapidly rising pressure. The separation at 10.2 produces additional turbulence; the layer returns to the surface at 10.8 inches and separates again at 12 inches. Such a phenomenon might be missed by short-cut methods, but the apparatus of Professor Jones should detect it if the surface tube is included. If only the outer tube is used, the phenomena of separation and transition cannot readily be distinguished.

It may be noted that if transition is produced as a result of laminar separation, the point of separation is independent of Reynolds Number only if the pressure distribution is independent of Reynolds Number. We have observed that a laminar layer may separate, exist as a free laminar layer for some distance, and then become eddying. In such cases as the transition point in the free layer moves forward, the pressure distribution around the body is modified and the location of the point of laminar separation varies with Reynolds Number.

We have used a hot-wire version of the surface tube, which has some advantages, and which we believe could be used in flight. The wire 0.00063 in. in diameter was mounted on a thin steel band 6 in. wide and 0.002 in. in thickness encircling the cylinder

and capable of being moved around the contour of the cylinder so that the wire traversed the boundary layer at a small fixed distance from the surface (about 0.008 in.). While the actual measurement of speed is not easy with this arrangement, a simple electrical circuit permits the rapid location of the point where the speed is a minimum which corresponds to minimum skin friction on the surface or to the minimum total head shown by Professor Jones' surface tube. The device has been quite satisfactory in the laboratory and can probably be used in flight.

With this apparatus we have made rapid surveys of the effects of wind-tunnel turbulence which will be described in a forthcoming paper by G. B. Schubauer. A sufficient increase in the turbulence eliminates the first separation and region of reversed flow and the results on the location of transition check fairly well G. I. Taylor's formula for the relative influence of intensity and scale of turbulence.

Another interesting result is that when the turbulence is lowered beyond a certain point, further reduction does not move the point of transition farther from the nose, suggesting that the transition is then controlled by the pressure distribution system rather than by the turbulence of the external flow. A similar effect of Reynolds Number is found at a suitable value of the turbulence, the transition point not moving aft of 6.1 inches as the Reynolds Number is reduced.

Oscillograph records of fluctuations fail to show the sudden and intermittent transition observed on the flat plate. The intensity and frequency increase continuously with distance from the nose. There is a rather high maximum intensity at the transition much like that observed at the California Institute of Technology on the curved plate. Thus when pressure gradients and curvature are present the transition appears to be of a different character. There seems to be little doubt that the intensity and rate of fluctuations in the boundary layer are dependent on the sign and magnitude of pressure gradient and on the curvature as well as on the turbulence of the air stream.

As further results of the research sponsored by the National Advisory Committee for Aeronautics and of that conducted by Professor Jones and his colleagues become available, it is hoped that the picture may become clearer.

Dr. W. F. Durand
Stanford University

Referring first to the broad domain in which the work reported by Professor Jones finds its place, and to the wholly admirable character of the paper, both as to its content and as to the character of the treatment, I should like to emphasize what seems to me the profound importance of the activity which has characterized our study of the laws of fluid mechanics, in the broad sense, during the past ten or fifteen years.

I am not referring alone to the importance of this work in connection with its aeronautic applications, but rather to the broad significance which these laws play throughout the entire domain of nature. Matter, broadly speaking, is either fluid (liquid or gaseous) or solid, and throughout the entire domain of natural phenomena, the activities with which we are concerned and which touch our lives most closely involve, in an impressive degree, the movement of a fluid, constrained or directed by a solid boundary; or more broadly, the relative movements of solids and fluids.

Thus the circulation of the blood in our veins and arteries; the movement of sap in trees; the flow of rivers and streams; the movement of the winds; the movement of water-borne and of air-borne craft—from such major class examples down to the most trivial actions as, for example, the agitation of a spoon in one's cup of coffee, in order to distribute more evenly the sugar in solution. These and thousands of other examples could be named, of activities or of natural functions, which touch our lives more or less closely and which all involve the phenomena attendant on the relative movement of solids and fluids; and thus mark the significance of the laws of what we call fluid mechanics.

And because of this, I hail with deep satisfaction the concentration of effort which these recent years have witnessed in the study of these phenomena, and in the better understanding of these laws which it has brought. And may not those who are especially concerned with the study of these laws in connection with the problems of air transport, take some measure of satisfaction in the thought that this study, on their part, will serve not only these immediate purposes, but also as a real contribution to a far wider domain of human activity; and that the refinement of laws which seems to be gradually developing out of such work as that described in Professor Jones' paper will find applications in domains of human interest far removed from those which have served as their immediate occasion. And may it not be said, that those who are thus serving the immediate interests of aeronautics, constitute, in effect, a service unit to all phases of human activity where a better understanding of the laws of fluid mechanics may enter as a significant factor.

Now with regard to Professor Jones' paper itself, I have been especially interested in his analysis of the conditions affecting the location of the transition point from laminar to turbulent flow, as expressible in terms of three non-dimensional parameters, and in the conclusion that three such parameters cannot include all the influential factors. In this connection the observations of Dr. Dryden regarding fluctuations in a laminar layer, and the suggestion of Professor Jones regarding the possible movement of the transition forward from the point of its initial formation, seem to me of special significance.

It seems quite clear that, as Professor Jones says, further observational work lies ahead—that until some adequate relation can be established between all further outlying essential phenomena and the basic conditions of the observation, we can hardly hope to be able to specify such additional parameter or parameters as may be required to give a complete account of the situation.

In the way of basic conditions affecting the observation, I have wondered regarding one characteristic of the air which, so far as I am aware, has not been usually taken into account as influential in connection with the study of these phenomena; and that is, the degree of ionization of the air. We have the physical characteristics of temperature, pressure, density, humidity, and viscosity; but may not, conceivably, the degree of ionization of the air be influential in connection with these obscure boundary phenomena? We know that it is influential in connection with other physical phenomena, as for example, the formation of rain droplets. Where we are approaching the ultimate in our study of this phenomena of the boundary layer, may it not be necessary to take some account of the electrical condition of the air as well as of its physical characteristics?

In closing, let me express my highest admiration for this paper and for the skill and resourcefulness with which the experiments were carried out. The researches here described belong to that supremely important type in which the locale is carried from the laboratory to the air, and to the condition of actual flight. And I am satisfied that, with this open door which has been provided by Professor Jones and his colleagues, these particular problems of the boundary layer will be carried through to some reasonably satisfactory and final conclusions.

Dr. J. C. Hunsaker
Massachusetts Institute of Technology

We are indebted to Professor Jones for a masterly survey of the state of knowledge regarding the breakdown of laminar flow, and in the true spirit of science he has given us the details of his own brilliant research results with an intimation of the direction in which they are leading him. Others who are working on the same problem are grateful for this disclosure and should respond in kind.

Professor Jones gives us evidence that the conditions for transition from laminar to turbulent flow cannot be expressed solely in terms of those parameters used in his experiments. However, I can add evidence that certain parameters are without doubt important.

At M.I.T., as a result of wind-tunnel research on flow separation and transition, we have good evidence that the transition point moves forward on a wing with increasing wind speed. Here the wing is held at a constant attitude and the only variable is the speed. Hence Reynolds Number must be a controlling parameter.

We also confirm the fact that the thickness coefficient N of Professor Jones' notation must be important. Dr. Peters using a similar coefficient based on the momentum thickness found that transition took place always at about the same value of this coefficient for a flat plate and a wing and, furthermore, both on the upper and lower surfaces of the latter. This thickness coefficient appears to have a critical value.

In our work on hydraulic cavitation we have observed a periodic phenomenon associated with the flow through the throat of a Venturi nozzle, which suggests an analogy to periodic separation of air flow.

If we assume, as suggested by Professor Jones, that the laminar layer tends to separate and that transient separation actually takes place at breakdown into turbulence, we are led to believe that the instantaneous pressure gradient inside the boundary layer will differ from the mean value in the flow outside and should perhaps cause separation. Such separation will certainly break the flow down into turbulence. In general, turbulence is observed to be caused by separation or discontinuity.

A transient separation will cause a corresponding fluctuation in the local pressure gradient in the boundary layer, which in turn could cause a periodic fluctuation in the transition point as has been observed. The phenomenon of transient separation could then repeat itself in the manner observed for hydraulic cavitation.

When conditions are right the flow of water next to the walls of the throat separates to form vapor and turbulence. The vapor collapses, causes a sudden change in pressure in the throat with a return to continuous flow and a repetition of the cycle. The frequency of the repetition is a function of speed for given setting of the apparatus.

I do not wish to strain the analogy, but it seems to indicate that boundary flow phenomena are extremely sensitive to fluctuating pressures.

As to the scatter of the points on Professor Jones' final figure, I should like to point out that the pressure gradient in the laminar layer must be extremely sensitive to surface condition and must be extremely variable along any practical surface. Minute surface variations can very plausibly furnish a trigger action for transient separation, and may explain the scattering of results of tests made with different surfaces and attitudes. I, therefore, suggest that we do not worry about Fig. 13, nor try to draw general conclusions from it in view of the several sources of disturbance yet to be investigated.

It is most valuable to have the evidence of Professor Jones and his Cambridge colleagues spread before us in such clear form. American workers in this field will be greatly stimulated in continuing the attack on this fundamental problem of applied aerodynamics.

Dr. George W. Lewis
National Advisory Committee for Aeronautics

Before discussing the lecture proper I would like to express the sincere pleasure of the National Advisory Committee for Aeronautics on the selection of Professor Jones, a member of the British Aeronautical Research Committee, to present the first Wright Brothers' Lecture before the Institute of the Aeronautical Sciences. I am sure that these lectures, carried on from year to year like those of the Royal Aeronautical Society, will be of great value in the advancement of aeronautical science, both in England and in this country. The National Advisory Committee has benefited often by the friendly and cooperative attitude of British research workers, so that I especially welcome this opportunity to share in entertaining a distinguished member of that group. We in this country who are primarily concerned with the scientific aspects of aeronautics look with great respect at the research staff of Cambridge University including, as it does, men of such eminence as Professor Jones and Professor Taylor.

Dr. Dryden has described to you the recent results obtained in our researches on transition in this country, so I wish to comment more on the engineering significance of Professor Jones' very interesting studies. Ever since the early days of flying, both manufacturers and research workers have been very much concerned with the problem of reducing drag, and it seems likely that this problem will continue to be important for some time in the future. It is of interest to note, however, that we are now entering into quite a new phase of the problem, and Professor Jones in his paper this afternoon has lived up to his reputation of being in the forefront of progress. We all remember his suggestion some years ago that the criterion of the aerodynamic cleanness of an airplane should be the closeness to which its drag approaches the drag of a flat plate of the same wetted area. Up to the present time our efforts have largely been directed toward making the ratio as low as 1. Now, however, we appear to be entering a phase of investigation to bring this ratio below 1, actually to reduce the drag below what has sometimes been considered an irreducible minimum. To the designer of ten and fifteen years ago the increments of drag coefficient of which Professor Jones has spoken would have seemed insignificant, but on modern aircraft they represent a very appreciable and important part of the total. This is a real indication of recent aerodynamic progress.

To me one of the most remarkable features of Professor Jones' work is the apparent simplicity and directness with which he has obtained data applying to the case of particular interest, flight. I do not doubt that in the course of the investigation there arose many difficult problems of experimental technique which it required the utmost ingenuity to solve. It is noteworthy that Professor Jones has obtained data on very complicated phenomena with what appears to be very simple, understandable, and easily operable equipment.

I want to congratulate Professor Jones for presenting for the first time some definite figures on the dimension and location of the boundary layer. This will enable the designer to form some kind of mental picture of the factors that he must consider in attempting to secure minimum skin friction.

I. I. Sikorsky
Sikorsky Aircraft Division, United Aircraft Corporation

The lecture of Professor Jones was extremely interesting from a scientific standpoint. It is very probable that the ideas expressed will be very important in the near future, even from the standpoint of practical aeronautical engineering.

Ten or fifteen years ago the analysis of parasite resistance of an aircraft usually would have included some dozen items, such as struts, wires, wheels and their supports, separate power plant nacelles, and various other items. The profile drag of the wing in this case represented a minor item and the progress of design could best be achieved by simply reducing the number of protruding parts and improving the mutual interference of what was left. This work of cleaning up an airplane is nearly completed at the present time and in a well designed, modern airplane, particularly in a large, long-distance ship of the immediate future, we will usually find only three items of parasite resistance remaining, namely, the wing, the body, and the tail surface. This being the case, the resistance of the wing, even excluding the induced drag, becomes a major item that may approach one half of the total, while the skin friction of the whole airplane may eventually reach 75 percent of the total resistance. This being the case, it is important to study the methods which would permit controlling and, if possible, reducing this major item of resistance.

An important secondary problem in connection with this question appears to be a theoretical or experimental study of the question as to whether the skin friction of an ideal surface can be further reduced by artificial methods. By this we mean whether the re-

maining resistance is a basic figure similar to the induced drag figure which, we believe, cannot be reduced for the aircraft of given weight or span.

In line with this, it might be interesting to extend the study to birds flying. Some competent investigators believe that birds sometime develop extremely high efficiency and L/D ratios that are far in excess of those obtained in aircraft. This factor is attributed to particular characteristics of wing feathers which permit the air to slip through, creating the effect of a boundary layer control. While I do not believe that birds really possess outstanding efficiency, yet further study may be of great interest. It is indeed extremely difficult because the tests that were made on wings of dead birds may not be identical to the conditions of a living bird.

Finally, we know at least two methods that would permit controlling the boundary layer and moving backward the point or region of transition from the laminar to the turbulent flow. These methods are the use of pressure or suction slots or the use of a sort of endless belt or built in rotors which would permit the surface of the wing to move backward at a velocity equal to that of the air stream. The latter method would probably eliminate entirely all separation. It appears important that aeronautical science should find out whether the weight and power expended on the operation of these or other artificial boundary layer control devices would be such as to leave room for improvement in performance of the aircraft.

In conclusion, I believe that we all owe sincere thanks to Professor Jones for discussing this very important question in such a remarkably clear and interesting way.

Eastman N. Jacobs
National Advisory Committee for Aeronautics

Owing to the lack of time I must forego the expressions I would like to offer of my admiration of Professor Jones' work, and pass on immediately to the subject of transition now under discussion.

From my standpoint the outstanding result of Professor Jones' lecture is that he has definitely shown what we have suspected for a long time: that extensive laminar layers must be recognized as possibly existing on actual airplanes in flight within the Reynolds Number range commonly encountered. As wind-tunnel operators, many of us have hoped that we could escape this conclusion. When large possible movements of the transition point are encountered, corresponding uncertainties about our drag predictions are introduced. The outlook for us is gloomy. We remember Baker's experiments also made in England in which he found in towing airship models in water that the drag was practically indeterminate until the transition point was fixed by means of a small cord attached around the forward surface of the model. In fact, Reynolds' classic experiments exhibited this same uncertainty. One rather definite results was obtained, *i.e.*, the lower critical Reynolds Number at which turbulence started in the tube tended to be suppressed. The uncertainty appeared when it was attempted to determine the highest Reynolds Number at which laminar flow was possible; the more care exercised in controlling experimental conditions, the higher were the Reynolds Number values obtained.

The turbulence present in the variable-density tunnel has accomplished much the same result as Baker's cord and Reynolds' initial turbulence but the results must now be regarded as pessimistic as compared with the lower drags that Professor Jones has obtained in flight under carefully controlled conditions. In fairness to the variable-density tunnel, however, it should be emphasized that the results may still be employed as conservative. If you ask us to predict how much lower drag you may hope for in flight, however, it appears that we wind-tunnel operators are on the spot.

In order to predict actual airfoil drag coefficients, it is clear that something must be known about the position of the transition point. On this subject Professor Jones has provided some important data and a significant analysis, but the work impresses me mainly as providing the necessary material for a first class mystery.

The subject is evidently a complicated one and Dr. Dryden in his discussion has pointed out further complications encountered during his investigation of the flow in the boundary layer about an elliptic cylinder. A simple partial solution of the mystery should nevertheless be sought.

Is it possible that the desired simplification may be reached through further complication? Dryden's investigations have shown, for example, that Pohlhausen's λ, which is described by the speaker as a non-dimensional measure of the local pressure gradient, is not an adequate parameter to describe the condition of the laminar boundary layer at least in regions of adverse pressure gradient where separation may be imminent. Von Kármán and Millikan, however, have worked out a more complicated method of analysis which von Doenhoff, of our staff, showed would give satisfactory results when applied to Dryden's measurements on the elliptic cylinder. Moreover, G. I. Taylor's suggestions about the nature of transition together with certain experiments under carefully controlled conditions of vanishingly small turbulence, including some made at our laboratory to study transition on a plate in the presence of an adverse pressure gradient, have indicated that, within limits, transition may be very closely associated with laminar separation.

Such considerations suggest a limiting extent of the laminar boundary layer and consequently a limiting position of the transition point. Perhaps the approach to the problem may thus be simplified by first considering the extent of this range in which the transition point may be expected to lie near the point of laminar separation. On the one hand this position is an important one because more extensive laminar layers would not even be desirable. We have seen in the smoke tunnel at low Reynolds Numbers the unfortunate result of a much more extensive laminar layer. The laminar layer separates, leaving a wide turbulent wake and a high form drag if transition does not occur shortly after laminar separation. On the other hand, less extensive laminar layers are also undesirable, owing to the drag increase. Consequently, this limiting position also represents the optimum one. Furthermore, one mystery of the subject paper would tend to be cleared up if this position were actually reached in the experiments under discussion; that is, why the point of transition frequently appeared to be so definitely fixed on the wing.

Time did not permit much quantitative consideration of Professor Jones' data but von Doenhoff kindly made the necessary calculation for the top velocity distribution curve of Fig. 9. To me it is significant that the calculated laminar separation point came out within approximately 2 percent of the chord from Professor Jones' tick indicating his measured transition point. The significance is that with sufficient care, smooth surfaces, and in flight in turbulent-free air, the range defining at least a close approach to the optimum transition position appears to extend to surprisingly high Reynolds Numbers, that is, the values of several million reached in Professor Jones' flight experiments. The question I have previously asked still remains: How much further can we go in maintaining these desirable low-drag laminar layers?

T. P. Wright
Curtiss-Wright Corporation

In this lecture I was struck, as I have been when reading the previous lectures Professor Jones has given, with the scientific approach which he makes to his research investigations, striving constantly for the building up of facts and exhibiting the necessary caution in their interpretation.

We all remember, I am certain, the fundamental importance of Professor Jones' 1929 lecture wherein he developed the conception of the streamline airplane, outlining the wastefulness of de-

sign as it then existed, inasmuch as sixty-six percent of the engine power was wasted in overcoming drag due to turbulence in the wake of forms of non-streamline sections used throughout. He pointed out the possibilities as well as the advantages of designing to truly streamline shape and I know that personally, I was tremendously impressed by the lessons he taught in that lecture as no doubt, were many others.

In 1936 Professor Jones showed that much of his oiginal idea, had been attained and that subsequently we must exert our energies toward producing a smoother surface which would reduce skin friction itself, thereby setting up a new ideal for which to strive. In that lecture he alluded to the possibility of moving the transition point so as to increase the proportion of laminar flow in the boundary layer at the expense of the drag producing turbulent flow.

In the present lecture, I am impressed with the scientific methods used by Professor Jones in obtaining and interpreting facts which he hopes will shed useful light on the factors governing the location of the transition point. (The following shows the parallel reasoning of scientists working on similar problems. Last Spring, Eastman N. Jacobs of our own N.A.C.A. gave a paper on the subject of laminar and turbulent boundary layer in which at one point he stated: "*The situation with regard to the airfoil drag is particularly serious because we have no equipment capable of studying the subject experimentaliy in the higher full-scale range of Reynolds Number in which we are at present most interested. Recourse therefore must be had to theory.*" The mechanical means (using the Pitot Transverse Method) which Professor Jones has so well described to us today has apparently filled this need.

Professor Jones has shown us clearly many facts pertaining to the effect on location of the transition point of smooth wings, of parameters which are determined by the Reynolds Number of the boundary layer, the pressure gradient, and the radius of curvature. Although he arrives at the conclusion that it is some parameter whose origin is to be sought in the system of flow of the wings themselves, I think he rather regretfully concludes that the particular parameters investigated did not, of themselves, permit satisfactory determination of the transition point location. His allusion to the possibility that fluctuations superimposed on the main flow in the boundary layer may represent a basis for a parameter which will be of great importance in the transition point question should be noted and is a fact also alluded to by Dryden and Jacobs. There may possibly be some analogy between instability of these fluctuations which, through causes yet to be determined, seem to transform a laminar flow to a highly turbulent flow, with the instability of wings or control surfaces which at certain speeds may be subject to small vibrations without increase in disturbance but which at slightly higher speeds lose control, so to speak, and go into a phase of extreme flutter.

I trust I will be pardoned for again quoting from Jacobs' paper of last Spring wherein he says: "*the present knowledge of wind tunnels makes it appear feasible to construct suitable equipment giving an airstream of effectively zero turbulence and capable of reaching the very large Reynolds Numbers for which engineers will very soon require reliable data.*" Here also, it appears that Professor Jones has in great part succeeded. The tunnel of non-turbulent flow described in his lecture represents a tool which should be extremely interesting and useful in continuing the general studies on the phenomena of transition point and the results of which studies, coupled with additional full-scale tests may, we hope, form the basis for another lecture by Professor Jones a year hence.

Quantitatively, it appears rather early to predict the order of performance improvement that may evolve from this research. Four or five percent speed improvement appears likely in a relatively short time, with some attendant increase due to the supersmoothness required to effect rearward transition point movement. Jacobs, I recall, was very optimistic.

With the streamline airplane closely approximated in our present air transports and with the growing appreciation of the importance of smoothness of surface in reducing skin-friction drag, it appears that the next ideal for which we should continue striving is the airplane surrounded in larger part by laminar flow, a goal toward the attainment of which Professor Jones has contributed so much. We have closely approximated the airplane of streamline form—now, (as Professor Jones has pointed the way by advancing our knowledge of it, and although it seems improbable and may prove impossible) let us strive for the airplane of laminar flow.

The repetition of the First Wright Brothers' Lecture by Professor B. Melvill Jones at the Athenaeum of the California Institute of Technology in Pasadena on Tuesday evening, December 21, was the occasion of the most outstanding meeting of the Institute of the Aeronautical Sciences ever held on the Pacific Coast.

Professor and Mrs. Jones were honored on the evening of December 20 by a reception held at the home of Dr. Th. von Kármán, and on the evening of the lecture, they were guests of honor at a dinner in the Athenaeum attended by over one hundred members and guests of the Institute. In addition to Professor and Mrs. Jones at the speakers' table there were: Robert A. Millikan, Th. von Kármán, E. P. Lesley, H. Bateman, Clark B. Millikan, Elliott G. Reid, Hall L. Hibbard, Arthur E. Raymond, A. L. Klein, Carleton E. Stryker and Norton B. Moore.

After the dinner and before the lecture, a short business meeting of the Los Angeles Branch was held. This Branch had applied for its charter on Founders' Day, and the meeting was its first since the charter had been granted. The Standard Form of By-Laws was adopted, and the following officers were elected for 1938: Chairman, Hall L. Hibbard; Vice-Chairman, Clarence L. Johnson; Recorder, Richard M. Mock; and Treasurer, E. E. Sechler. Another meeting of the Branch will be held on Friday, February 11.

At the lecture, a wire from Major Gardner was read: "*Greetings from the Institute on occasion of holding first Wright Brothers' lecture on West Coast and organization of our most active Branch. Our sincere appreciation to Professor Jones for his willingness to give his important paper before our Southern California members.*"

Clark B. Millikan introduced Professor Jones, whose splendid lecture was enjoyed by well over two hundred listeners, and which was followed by a lively discussion entered into by Th. von Kármán, F. H. Clauser, H. Bateman, A. E. Lombard, and others.

Francis H. Clauser
Douglas Aircraft Company

It was a pleasure to hear from the man who provided the stimulus some years ago which has lead to the practical elimination of unnecessary form drag in modern airplanes and it is reassuring that this same man is now engaged in research which may conceivably reduce the remaining skin friction to some fraction of its present value.

One interesting point of the talk was the extremely small roughness necessary to precipitate transition. I wonder if Professor Jones has any data on either this effect or on the effect of roughness on the skin friction of the turbulent layer which might be compared with the permissible roughness given by current theory.

The speaker's remarks suggested the possibility of shaping the lower wing profile such that $dp/dx = 0$ at cruising velocities and thus preserving the laminar layer to great lengths over the sur-

face. I wonder if he has attempted anything along these lines.

It would be of interest to know Professor Jones' ideas on the possibilities of drag reduction by boundary layer removal at the points of transition, thus having only laminar layers on the wing profile.

Lastly, what are Professor Jones' fondest hopes regarding large drag reductions by preserving the laminar layer throughout the entire length of the boundary layer? Here Professor Jones may cast scientific caution to the winds and speculate as in his fondest dreams.

Letter to the Editor

December 17, 1937

Dear Sir:

In the April, 1937 issue of the Journal, R. S. Hatcher published an article on "Rational Shear Analysis of Box Girders." In the November, 1937 issue, George N. Mangurian published, in the form of a "Letter to the Editor" a set of formulae which is both more general and much simpler. For the benefit of younger students, who might become confused, it seems very desirable to say a few words on the physical meaning behind Mangurian's formulae.

Inspection identifies Managurian's basic formula for e as established by the oldest approximate method in existence, the so-called Centroid of Inertia method. This method was established in the days of wooden two-spar wings and gives very good approximations for true two-spar structures. For box-beams, however, it holds only if their action resembles that of two-spar wings. The indiscriminate application of the method to box-beams may lead to disastrous consequences, as shown in the following example.

Fig. 1 represents a fairly common type of construction, the nose and the tail furnishing no structural strength. Now it has been sometimes practice to pierce the rear shear web with large round holes to give access to the interior of the wing. This reduces the effective thickness t_2 practically to zero. Substituting $t_2 = 0$ in Hatcher's formula gives the elastic center location as H, while Mangurian's formula gives M. Reference to any good text book on strength of materials will show that Hatcher's location is the correct one.

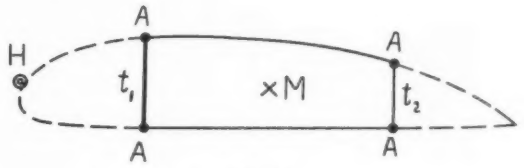


FIG. 1.

Assuming a load applied at 50 percent of the wing chord (old L.A.A. case), Mangurian's formula gives only bending, no torsion, while Hatcher's formula gives correctly a very heavy torque added to the bending. This error is the more serious because the box considered is weak in torsion.

The distribution of stresses in a box beam is a statically indeterminate problem. For more than half a century it has been a recognized principle of engineering mechanics that such problems can be solved only by taking into account the elastic properties of the structure. It is not always possible to do this very completely, but any rule such as Mangurian's which violates a very important condition should be ear-marked very clearly as a sort of rule-of-thumb, very useful in the hands of a man who knows when not to use it, but a dangerous tool to put in the hand of a neophyte.

PAUL KUHN
National Advisory Committee for Aeronautics

Book Review

Mussolini Aviator, by GUIDO MATTIOLI; L'Aviazione, Rome, 1937; 250 pages, illustrated.

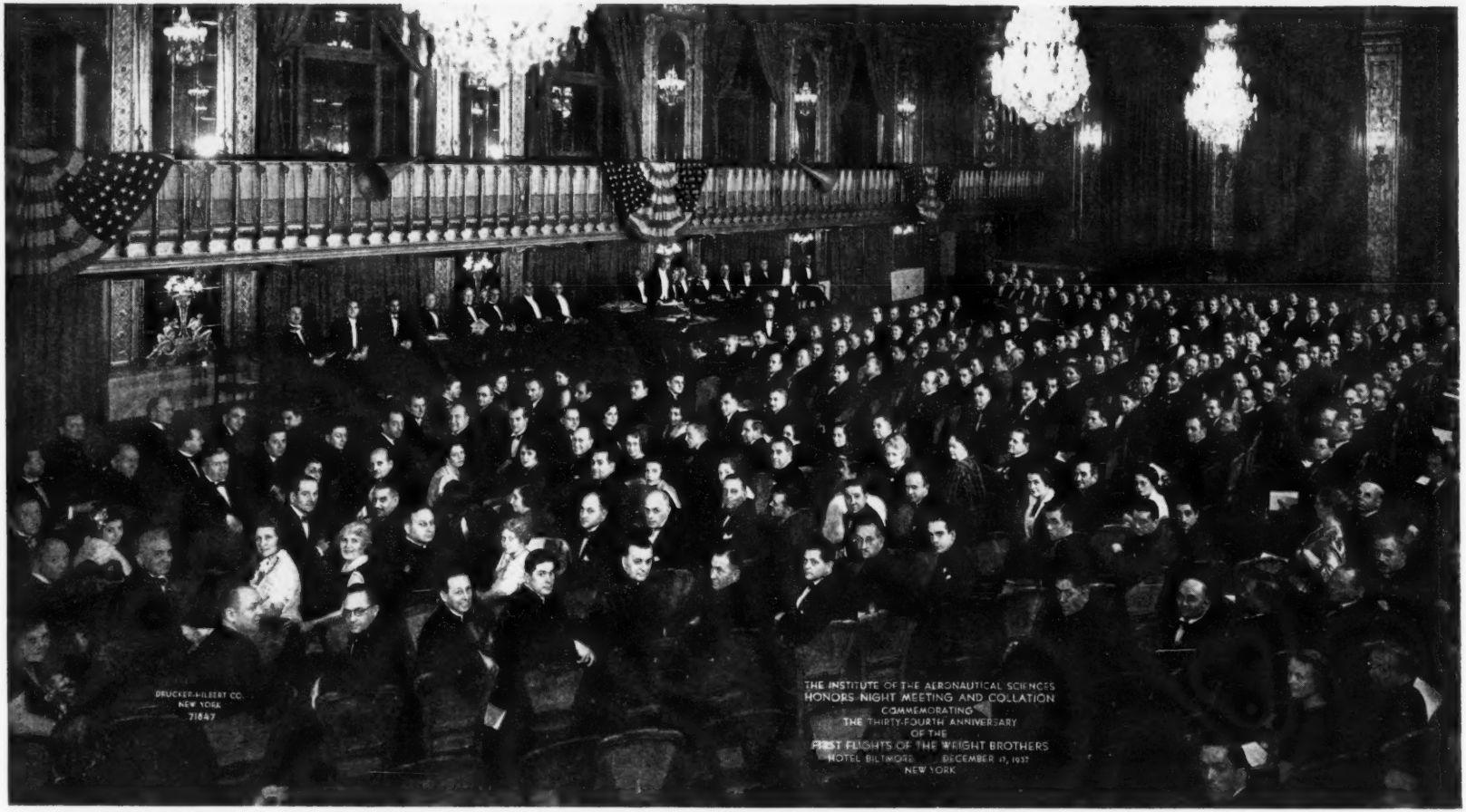
No history of Italian aviation could be written by a better informed observer than Guido Mattioli. He has seen it grow from its earliest period, followed it as editor of L'Aviazione through its tragic depression after the War and finally gloried in its astonishing expansion which has had not only the will but the fist of the Duce to urge it on to greater and more impressive triumphs. Mattioli, with his wide international acquaintance, has written a score of books on Italian aeronautics with a full knowledge of what is going on in other parts of the world. They are, therefore, not insular but bring together a world point of view which makes them of the greatest interest to those who are anxious to learn more of the vast development now going on in the factories and on the flying fields of Italy.

Two years ago he published his biographical sketch of Mussolini in Italian. This volume is a translation in English which, owing to the limited edition, has evidently been printed for the information of friends who are not able to read Italian.

Anyone who knows anything about Italian aeronautics knows that Mussolini is its mainspring. No matter how complete his controlling influence on the destinies of other activities of Italy, his direction of its air activities is based on his personal experience as a pilot, his enthusiasm for flying as a sport, and his belief, in accordance with that of his associate, General Giulio Duhet, that the destiny of Italy can be achieved best with the strong argument of a powerful air force. This book gives the reader a carefully drawn picture of the close relationship of Italian aviation and Fascism. Its warp is Mussolini's constant personal interest in all phases of aeronautics and its woof is the resulting completeness of aeronautics in Italy. From the earliest days of his political career, the Leader has used aircraft as has no other propagandist, politican or statesman. It has not only served him well but provided another outlet for that seemingly unlimited energy which is driving his country to a more ambitious place in the sun.

Mattioli did not write a biography. He wrote a history of Italian aviation with its directing genius as a binding which holds it together and covers it accomplishments. The text, supplemented by many illustrations, will give anyone who wishes to see what a great force can do to an immovable body, an example which may have lessons for other countries. When war comes, the same pressure is exerted on all armament requirements. Mussolini has not waited for this urgent need. He wants to be prepared before hand. This is the fundamental lesson that should be gained from reading this book.

LESTER D. GARDNER



HONORS NIGHT MEETING
NEW YORK, DECEMBER 17, 1937

On dais from left to right: B. C. Boulton, Hon. E. P. Warner, Eastman N. Jacobs, Commander C. E. Rosendahl, Dr. George W. Lewis, Major General O. Westover, U. S. A., Dr. Harvey N. Davis, Professor B. Melvill Jones, Hon. Harry F. Guggenheim (standing), Chairman, Dr. Clark B. Millikan, Glenn L. Martin, Dr. W. F. Durand, Dr. Lyman J. Briggs, Willis R. Gregg, T. P. Wright, Clarence L. Johnson, Elmer A. Sperry, Jr., P. B. Taylor. At table: Major Lester D. Gardner, Secretary, Institute of the Aeronautical Sciences. Center front row from left to right: Col. Charles A. Lindbergh, Orville Wright, Dr. Hugh L. Dryden, W. Starling Burgess, Luis de Florez, Arthur Nutt, Dr. James H. Kimball, H. J. E. Reid, Leroy R. Grumman, C. H. Chatfield, Dr. Stephen J. Zand, P. R. Bassett, Dr. J. C. Hunsaker.

Honors Night Meeting of the Institute of the Aeronautical Sciences

Commemorating the Thirty-Fourth Anniversary of the First Flights of the Wright Brothers
Hotel Biltmore, New York, December 17, 1937

THE first Honors Night Meeting of the Institute of the Aeronautical Sciences was held on December 17 as part of its program arranged for the commemoration of the first flights of the Wright brothers. Mr. Orville Wright attended as an Honorary Fellow of the Institute. This was the first aeronautical meeting Mr. Wright has attended in New York for over twenty years. Colonel Charles A. Lindbergh also attended as a Fellow of the Institute. About five hundred members and guests were present to hear the program.

Before the meeting a small dinner was given in honor of the guest speakers, the recipients of awards and honors, and the National Advisory Committee for Aeronautics. Each guest at the meeting was presented with a boutonniere, the flowers of which had been picked in California the day before and sent by airplane overnight to New York through the courtesy of the Air Express Division of the Railway Express Agency.

There follows a condensed transcript of the meeting. There has been no opportunity to submit the stenotype report to the speakers and therefore they should not be held responsible for the strict accuracy of their remarks. Formal salutations are omitted from all except the first two introductions.

President's Introduction

Dr. Clark B. Millikan: Mr. Chairman, Distinguished Guests, Fellow Members of the Institute, Ladies, and Gentlemen: It gives me the greatest of pleasure to welcome you on behalf of the Institute of the Aeronautical Sciences to this, its first Honors Night.

The occasion has a threefold significance, which gives it a special timeliness and importance. First, it marks the thirty-fourth anniversary of the famous flight which ushered in the present aeronautical era and crowned the years of study and research of the Wright brothers.

It is a special honor and privilege to welcome Orville Wright in person and to have the opportunity of paying him the tribute with which we shall later close our evening.

Second, this is the first time at which the Daniel Guggenheim Medal, the Reed and Sperry Awards of the Institute of the Aeronautical Sciences, and the Honorary Memberships and Fellowships of the Institute have been formally presented on one occasion.

In this connection, I should like to express our appreciation to the Directors of the Daniel Guggenheim Medal Fund who, after attending the dinner in honor of Dr. Lewis last year, decided that in the future the medal would be presented on Honors Night.

Finally, this occasion furnishes an opportunity of extending our greetings and appreciation to the distinguished scientist, Professor B. Melvill Jones, who has come from England to deliver the initial Wright Brothers' Lecture, which many of you were fortunate to hear this afternoon.

Since the first two aspects of our evening will occupy most of the program, I should like to say just a word in connection with the inauguration of the annual Wright Brothers' Lecture. Inspite of the ever increasing influence of aviation upon international affairs and of international developments on the technical progress of aviation, there has in the past been no regular function in this country to which distinguished foreigners were invited to discuss the aeronautical problems of their countries.

The annual Wright Brothers' Lecture now fills this gap and I feel sure is destined to play a role of fundamental importance in promoting international understanding.

The inaugural lecture, this afternoon, set a standard of excellence which will be hard to maintain in the future. We hope that the Wright Brothers' Lecture will attract a donor who will endow the lecture, as has been done with the Wilbur Wright Memorial Lecture in England. No one could make a greater contribution to the promotion of international understanding, to the disclosure of aeronautical knowledge and the honor of this anniversary, than by becoming a benefactor of the Wright Brothers' Lecture.

Again, the Institute is indebted to Mr. Guggenheim, who acted as Toastmaster last year, for agreeing to act as your Chairman this year. We honor him not because he is the son of that great benefactor of aviation, the late Daniel Guggenheim, but because of his own great and continuing interest in aeronautics.

Chairman's Introduction

Hon. Harry F. Guggenheim: Dr. Millikan, thank you for this most gracious introduction.

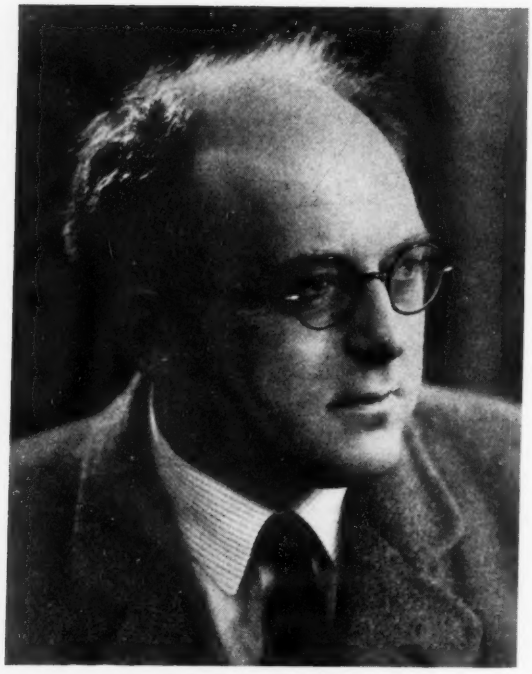
Distinguished Guests, Ladies, and Gentlemen: Last year, when I had the honor of presiding at the Institute's meeting, I let you all behind the scenes so that you might look at Lester Gardner motivating the illustrious speakers and distinguished guests, like some intellectual Tony Sarg pulling the strings of his marionettes.

This year, when Lester Gardner again honored me by inviting me to preside at your meeting, I felt that it must be due to that insistence of his, that no member of the Institute ever be lost, no friend of the Institute ever be lost, and evidently, that no presiding officer *pro tempore* be lost.

The meeting tonight is one in which no friend of the Institute or in fact, no partisan of aeronautics could fail to feel a special honor in taking part. Thirty-four years ago on this day, the Wright brothers achieved for the first time, power-driven flight. Recognition was very slow in coming.

Yesterday at a meeting in Washington, Mr. Wright recounted a gem of an aeronautical anecdote that I am sure he would not mind my repeating to you.

He said that immediately after the flight, he and his brother drove a long distance to the nearest telegraph station and sent a telegram to their father telling him of their flights. The telegram was received by the telegraph operator at Dayton and apparently the telegraph operator, being a great chum of the local Associated Press correspondent, thought he would do him a good turn and gave him the telegram. The AP correspondent, this



Professor B. Melvill Jones

news sleuth, shook his head. He said, "No, there's no news in that. 59 seconds! If it had been 59 minutes, I could use it. There's no news there."

Inauguration of Wright Brothers' Lecture

For thirty-four years, various efforts have been made to commemorate adequately this flight, and in various parts of the country, there have been demonstrations and celebrations. They have been for the most part local and non-recurrent. This is the first time that this event has been commemorated in such a distinguished manner. I have no doubt that the combination of the Wright Brothers' Lecture and Honors Night of the Institute will be an event that will be recurrent from year to year.

The Institute, in establishing the Wright Brothers' Lecture, has followed the precedent set by the Royal Aeronautical Society of England. For many years, there has been a Wilbur Wright Memorial Lecture. In accordance with the usage in England, one year the lecturer is a foreign guest and the next year, an Englishman. In like manner, the Wright Brothers' Lecture will be given one year by a foreign guest and lecturer, and the next year by an American.

One of our distinguished guests tonight, Professor Jones, delivered the first Wright Brothers' Lecture this afternoon at Columbia University. Those of you who had the opportunity of listening to that lecture realize full well what a great contribution it was to aeronautical science.

Appreciation to R. Ae. S.

Professor Jones, when you return to England, will you, on behalf of the Institute, express the deep appreciation of our Institute to the Royal Aeronautical Society for permitting us to share with you in the use of the name "Wright" which you first chose. Will you also express to them the hope that we cherish, that in the future, as we had today, the lecturers will be men of such distinction as yours have always been, that we too may add to aeronautical science by their choice.

Professor B. Melvill Jones: Thank you. I will carry your message to the Society.

Greeting to Orville Wright

Mr. Guggenheim: Thirty-four years ago today, two men gave to the world, aviation. One of those men sits with us here tonight. He was the first Honorary Fellow of the Institute.

When he received a notice of this meeting, he accepted it, and he sent his acceptance with his check and an application for a seat. Those of us who have had the great privilege of working with Orville Wright will not be surprised to hear that incident. It is characteristic of the man.

He has come here tonight, not to be honored, but to do honor to our guests. We shall respect his fine sensibilities and not ask him even to rise to accept that great homage that is in our hearts and that we all feel we would like to give to Orville Wright.

Mr. Wright, we are indeed grateful to you for coming here.

Greeting to Colonel Charles A. Lindbergh

Ten years ago, another American dramatized aviation for the world. He, too, sits here with us tonight, and he comes to do honor, not to take it.

One of the paradoxes of America, I think, is that in this age of showmanship some of our most dramatic heroes are our most modest citizens. Colonel Lindbergh, we thank you for your participation tonight in this ceremony.

How dramatic the last thirty-four years of world achievements in aeronautics have been, I think can be summed up in a single sentence. From that beginning of 59 seconds of flight, if my memory serves me correctly, we have now achieved speeds of 440 miles per hour, altitudes of 54,000 feet, non-stop range of 6300 miles, a plane of 60 tons carrying 69 passengers for an hour, and engines of as great as 3100 horsepower.

The first honors to be presented are Honorary Fellowships, and I shall call on Dr. Millikan for the presentations.

Presentation of Honorary Fellowship to Professor B. Melvill Jones

Dr. Millikan: Each year the Institute has the pleasant privilege of presenting to two outstanding aeronautical workers, one foreign and one American member, Honorary Fellowships, symbolic of the esteem in which the contributions of the recipient to the development of aeronautics are held by the body of Fellows which carries out the election.

Last year's choice for Foreign Honorary Fellow and the decision to withhold the formal award until tonight, combined in a peculiary fortunate manner, in that the new Honorary Fellow has just given us a beautiful demonstration of his fundamental contributions to contemporary aeronautics.

Professor B. Melvill Jones' membership in the academic profession may be viewed either with alarm or respect. When it is combined with his many years of experience as a practical pilot and his invaluable services to the British Air Ministry in connection with the actual construction and operation of aircraft, the combination indicates an almost unique catholicity of interest and achievement in aeronautics.

The subject of Professor Jones' recent researches upon which he spoke this afternoon and which constitute the formal basis upon which his election to Honorary Fellowship was decided, combines in a remarkable way the extreme interest for scientists' work with the fundamentals of fluid mechanics and an immediate importance for the practical designers, builders, and operators of aircraft.

Professor Jones, it gives me great pleasure to present you, a Fellow of the Royal Aeronautical Society, with the certificate of Honorary Fellowship in the Institute of the Aeronautical Sciences, *"for contributions to the science of aeronautics, for in-*

troducing the conception of the ideal streamlined airplane, and for full scale research work on boundary layer flow."

Acceptance by Professor Jones

Professor B. Melvill Jones: I have first to express my thanks to the Institute of the Aeronautical Sciences for electing me to an Honorary Fellowship and to Mr. Guggenheim and to our President for the graceful words which they have said about me tonight.

I can assure you that I have a very lively appreciation of what it means to be an Honorary Fellow of an organization which is already, in spite of its youth, taking its place amongst the leading scientific bodies of the world.

Next, I wish to thank the Institute for providing me the occasion, which has enabled my wife and myself to realize an ambition which we have long held, to visit your great country. I had never imagined that when the opportunity to visit you came, it would come in such a magnificent form.

In England, the hospitality of the United States is so well known as to become almost a byword, but to realize to the full what it can mean, one must pay a visit under the auspices of your efficient and energetic Secretary, Mr. Lester Gardner.

Were I not experiencing it in person, I would not have believed a program of visits and entertainments such as he has prepared for us, to be possible, but so far it is going well and I am still alive, and so, may I say, is my wife.

When I realized that I was to deliver the first of a series of lectures, many of which in the future will, I have no doubt, become classics of aeronautical literature, I was exceedingly alarmed, but I comforted myself with this thought; great enterprises often start in a very lowly form and it is much better that your lectures should start at the bottom and work upward in excellence, than that they should start at the top and work downward. With this idea in mind, I was emboldened to accept your invitation, but I will say I was very frightened.

We of the older organization, may I say the parent organization, the Royal Aeronautical Society, are surprised and pleased to note the rapid growth of a society which as far as I can see, seems glad to be regarded as one of our descendants. In watching your rapid growth, we feel that we have to look to our own laurels.

In private life, I am myself a parent and I am therefore in a position to explain to those of you who are not yet parents that there is nothing a parent likes better than to see his child surpass himself. I can assure you that we realize that the competition amongst friends, such as we always hope to be, is a most valuable spur to progress. We wish you unlimited success in all the activities which you may undertake.

May I take this opportunity of thanking again our Chairman, Mr. Guggenheim, on behalf of the Royal Aeronautical Society for the generous way in which you came forward at a critical period of our Society's history and helped us out of a very difficult financial position. I can assure you that we appreciate as much, or more, the spirit in which you did this as we appreciate the great and very real help which you gave us in a time of difficulty.

It is to me, personally, a most particular pleasure to have the opportunity to meet in person Orville Wright, in whose honor this gathering is made, and Colonel Lindbergh, whom it has been my ambition to meet for a long time. These two are, I think, without doubt the most famous personalities in the world of aeronautics at the present time. How very greatly the Royal Aeronautical Society of England respects the work of the Wrights is shown, as you have heard here, by the fact that they have made the Wilbur Wright Memorial Lecture the principal event of their year's program.

I had intended to convey to Mr. Wright, privately, the great regard which the Royal Aeronautical Society of England has always had for his work and for the work of his brother, but I am now glad to be able to convey that appreciation to him in public and in the presence of the members of our Institute.

In England, we have been very pleased and proud to extend the hospitality of our country to Colonel Lindbergh. We people who live in universities, know the value of peace and retirement for the prosecution of research and we sincerely hope that Colonel Lindbergh has found in our country, conditions favorable to the work upon which we know he is engaged.

I will not keep you longer from the distinguished persons who are going to speak on our program, and I close on a note of sincere thanks to you and to all for the welcome which you have extended to us in our first visit to your country.

Presentation of Honorary Fellowship to Glenn L. Martin

Dr. Millikan: The last time that I had the privilege of sitting next to Glenn Martin, who has been chosen by the Fellows of the Institute as the American Honorary Fellow for 1937, was last spring at Newport Harbor Yacht Club in Southern California. The occasion marked the celebration of the first long over-ocean flight which Glenn Martin had executed twenty-five years before from Newport Bay to Catalina Island and return. The commemorative ceremonies concluded with a flight over the original course in the latest China Clipper which, the next morning, started on its routine flight to China.

The incident is illustrative of the remarkably long span covered by Mr. Martin's creative contributions to aeronautics. The flight in the China Clipper was significant in showing that even after this long period of activity, his contributions are still continuously increasing in magnitude and importance. The great flying boat launched this month and built for the Soviet Republic is the largest and one of the most remarkable flying boats ever built in this country and it is a matter of common knowledge that his plans for the future surpass in conception anything that he has as yet achieved.

It is a special privilege to be able to present this certificate of Honorary Fellowship *"for outstanding achievement in the construction of notable aircraft of all types"* to a past President of the Institute, who has always taken such a deep interest in its development.

Acceptance by Mr. Martin

Mr. Glenn L. Martin: It is a great honor to receive this Fellowship. To be elected an Honorary Fellow by the Fellows of the Institute is a recognition that one appreciates more than many things that happen to one in a span of life. I express my deep appreciation of the honor. Thank you.

Mr. Guggenheim: May I be the first to congratulate the recipients of these awards? I have known Professor Jones for about eleven years. When we were making a survey of aeronautics in Europe and, of course, in England, it was one of my pleasant duties to visit Cambridge and talk to Professor Jones. Even in those days, his name in America was well known and the work that he was then doing was envied by many of us here.

It is indeed a pleasure for me to congratulate him tonight after eleven years of such distinguished aeronautical contributions on his part.

My friendship with Glenn Martin dates back at least to that time. During these years, he has been so conspicuous in his energy, ability, and persistence, in the development of aircraft, that we are all happy that this honor has come to him.

And now, we come to a part of the program that is of personal interest to me. It is the bestowal of the award that my father created.

At the time that the Medal Fund was created, it was placed in the hands of a self-perpetuating Board. Certain general conditions were suggested to the Board, and after that, the administration was left entirely in their hands. Since the creation of the award fund, many busy men have devoted time and special

attention to the award, and I wish to express my deep appreciation of their energy and ability, devoted to this work.

Four of the previous recipients of the award are here tonight. Mr. Wright, Dr. Durand, Dr. Hunsaker, and Dr. Lewis. The mere mention of those names will indicate to all of you with what great care these selections have been made.

In presenting the President of the Fund for this year, I wish to express my great appreciation to him for the efficient administration of the work of his Board. I now take pleasure in presenting to you T. P. Wright, President of the Daniel Guggenheim Medal Fund!

The Daniel Guggenheim Medal Fund

Mr. T. P. Wright: The Daniel Guggenheim Medal Fund was created for the purpose of honoring persons who make notable achievements in the advancement of aeronautics. It is also, however, a commemoration of the support given by Daniel Guggenheim to the advancement of aeronautics, to donations for the creation of schools of aeronautics, and for the encouragement of civil aviation.

All interested in aviation recall the safe aircraft competition and the inauguration of a program which had in view the advancement of the art of fog flying and landing. The numerous Daniel Guggenheim Laboratories and schools of aeronautics located at leading colleges throughout the country are in evidence to anyone who has occasion to visit our universities.

Provision for the Medal was made in 1928 by a gift from the Daniel Guggenheim Fund for the Promotion of Aeronautics. A word on the establishment of this munificent Fund would, I am sure, be of interest. Our Chairman tonight, Harry Guggenheim, possessing a love and appreciation of aviation, interested his father likewise so successfully that his father established the Daniel Guggenheim Fund for the Promotion of Aeronautics with a most generous endowment.

Throughout the life of the above Fund, Harry Guggenheim, its President, suggested many of the useful projects which it has sponsored. He also took a keen interest in its affairs and administration.

This Fund, so carefully administered by Mr. Guggenheim, with the able assistance of Rear Admiral Cone and Rear Admiral Land, passed out of existence in 1930, having expended its substance in the many projects which it carried out, promoted, or endowed.

One of these was The Daniel Guggenheim Medal Fund, organized in 1927. One-third of the members of this corporation are members of the American Society of Mechanical Engineers, one-third are members of the Society of Automotive Engineers, and one-third are members of the Institute of the Aeronautical Sciences. The Board of Award is international. It has for members the nine Directors of the corporation and one member from the following foreign countries: From England, Griffith Brewer; from France, Professor Albert Caquot; from Germany, Dr. Friedrich Seewald; from Holland, Dr. E. B. Wolff; from Italy, General G. A. Crocco; and from Japan, Professor Koroku Wada.

The medal is of gold and awarded not more often than annually with no restriction on account of race, color, nationality, or sex. Selections are made by the Board of Award approximately a year in advance and a two-thirds vote of the entire Board is necessary for selection.

The recipients of the award form an imposing list of leaders in aeronautical science and in aviation in general. You have been given a booklet which lists on its cover the past recipients of the Medal with a biography of each. The first award, you will note, was made in 1929 to Orville Wright. This year, for his notable achievement in the advancement of aeronautics, the name of another illustrious man is to be added to the list of those who have received The Daniel Guggenheim Medal.

George Mead Honored by R. Ae. S.

Mr. Guggenheim: May I read a cable from the Royal Aeronautical Society which requires immediate attention. The cable says: *"George Mead has been awarded the Taylor Gold Medal for the best paper given before the Society in 1937."*

We all extend our congratulations to Mr. Mead and regard it as a great honor for a distinguished American engineer to be selected for such an award. I wish him to accept on our behalf, our admiration and congratulations.

Mr. George Mead: Thank you very much.

Mr. Guggenheim: We all regret that that rugged pioneer of airships, Dr. Hugo Eckener, is not here in person to receive the Medal. Two months ago, he wrote that he would be here but later, his health made it impossible for him to take the voyage.

As soon as it was learned that Dr. Eckener could not attend the meeting, he was asked to whom the Medal should be given and he immediately requested that Commander Rosendahl, the leading exponent of airships in this country, accept the Medal in his place. It was a happy choice indeed. There is no one, certainly, in America, in whose hands we would rather place this cherished Medal.

This Medal will be presented by the President of one of the oldest and greatest of our engineering societies, the American Society of Mechanical Engineers. In addition to his presidency of this great body, Dr. Davis is also President of the Stevens Institute of Technology.

Presentation of Daniel Guggenheim Medal

Dr. Harvey N. Davis: The American Society of Mechanical Engineers appreciates the honor of participating in the administration and the presenting of The Daniel Guggenheim Medal.

Since its creation, we have sought to assist in making it preeminent among aeronautical awards by honoring with it leaders in aeronautics and adding their names to the list of recipients.

I may add, parenthetically, that it is a matter of peculiar pleasure to me personally to participate in this ceremony because I have had a very keen interest as an outsider in aeronautics ever since the day when, as a minor official of the first Harvard Aviation Meet, I had the pleasure of assisting to check officially the establishment of a new world's altitude record for airplanes at something like twelve hundred feet.

Ever since the day a little later at Belmont Park Meet, when I saw one of Mr. Wright's planes ascend in the face of a moderate wind to establish a much higher altitude record and, with throttle wide open, sail gently backward down Long Island Sound, and had the pleasure of learning the next morning that after the wind had fallen and the dawn had come, it had managed to fly back again to the home field. Ever since the day a little later than that, when, as a civilian employee of the War Department, it happened to fall to my lot to send a telegram on Armistice Day that held on the dock in New Orleans what would otherwise have been the first shipment of helium to the American Expeditionary Forces in France; ever since the day, a little later than that, when I was rash enough to predict not only in private but in public, that commercial transatlantic aviation was a matter of the very near future and then had to wait five or six years to see that prediction come true, my faith in aviation never wavered during those years and it is as strong now as ever.

Tonight, we are to add a ninth distinguished name to this list of medalists by conferring the Medal, *in absentia*, on Dr. Eckener. We all wish that Dr. Eckener could have been here to receive it in person. None of us, however, would have wished him to imperil his health, which we hope will improve rapidly and let him continue to lead in the development of his special field.

To attempt to review the life of Dr. Eckener would bring you nothing new. You all know of his pioneering efforts at Friedrichshafen with Count Zeppelin and how, after his chief died, he carried on and became one of the great figures of the world. I am particularly impressed by that part of the citation which gives him credit for the international aspect of his work. In my opinion, the engineer who can change the course of world events has achieved one of the greatest aims of our profession. Dr. Eckener has done this by a tremendous demonstration of faith. He has

Dr. Hugo Eckener

taken the old Graf Zeppelin and the Hindenburg to many countries of the world in an air crusade that has created an interest in airships in all parts of the globe.

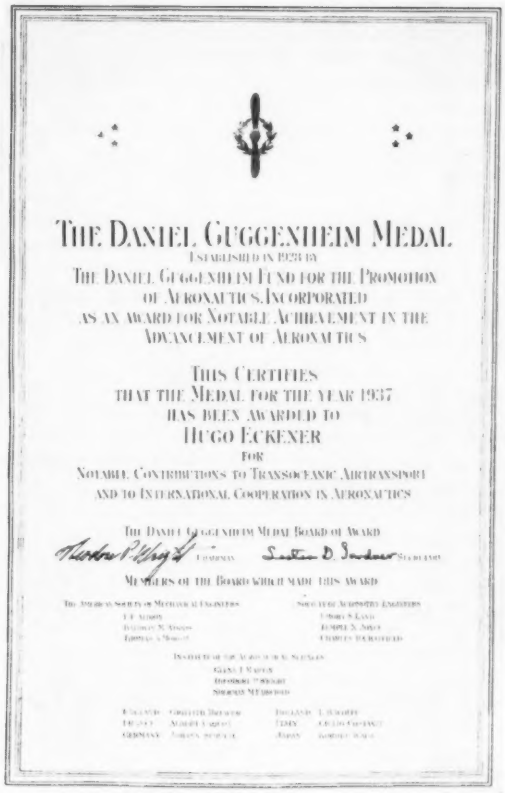
Often on these trips, he has had with him a gallant American officer, whom we all admire. Dr. Eckener has designated him to receive the Medal for him tonight. I take pleasure in presenting to Dr. Eckener through you, Commander Rosendahl, The Daniel Guggenheim Medal for 1937, together with this certificate which states that the award has been made *"for notable contributions to transoceanic air transport and to international cooperation in aeronautics."*

Acceptance of Medal for Dr. Eckener

Commander C. E. Rosendahl: As a fellow-believer in airships, in approaching this task of accepting for Dr. Eckener the Guggenheim 1937 award, I do so in all the humility and with all the respect that a pupil can have for a great master. As a proponent of airships then, I know of no greater honor than my present duty of accepting this richly deserved award for Dr. Hugo Eckener.

It has been my great privilege to know this youthful old gentleman on a personal basis as well. I have motored with the Doctor and his family through the beautiful Black Forest hearing him all the while relate American stories and stories of the United States that even my best American story-telling friends hadn't told me. I have heard him draw laughter from a Japanese crowd by his use of Berlin slang while addressing them. He has indeed a grand sense of humor. Goodness knows, airship advocates the world over have needed something besides hydrogen and helium to keep their spirits buoyed up during the trials and tribulations, the ups and downs of airships. While seated at dinner on the banks of Lake Constance, I have heard Dr. Eckener relate early airship experiences and incidents which that cradling ground of airships had witnessed over many years. I have seen him in many jovial and a few serious moments in the control car of an airship. I have followed him through the gastronomical and oratorical maze of numerous banquets and receptions not only over the United States but around the world as well.

Dr. Eckener drew up the following brief statement that he has asked me to read to you assembled here this evening:



THE DANIEL GUGGENHEIM MEDAL

ESTABLISHED IN 1929 BY

THE DANIEL GUGGENHEIM FUND FOR THE PROMOTION OF AERONAUTICS, INCORPORATED

AS AN AWARD FOR NOTABLE ACHIEVEMENT IN THE ADVANCEMENT OF AERONAUTICS

THIS CERTIFIES

THAT THE MEDAL FOR THE YEAR 1937

HAS BEEN AWARDED TO

HUGO ECKENER

FOR

NOTABLE CONTRIBUTIONS TO TRANSOCEANIC AIRTRANSPORT AND TO INTERNATIONAL COOPERATION IN AERONAUTICS

THE DANIEL GUGGENHEIM MEDAL BOARD OF AWARD

Chairman Secretary

MEMBERS OF THE BOARD WHICH MADE THIS AWARD

Message from Dr. Eckener

"In all truthfulness I can say that rarely, if ever, have I been more pleased over any distinction or token of appreciation that has been accorded me for my activities in the field of lighter-than-air aeronautics than over this award of the Guggenheim Medal. This great pleasure and appreciation has for its basis two reasons: First, I fully appreciate the high honor which this award carries with it; and second, I was especially gratified at the propitious time chosen for making this award to me. I was informed of this great honor immediately after the *Hindenburg* catastrophe. I believe I am justified, therefore, in interpreting this award not only as a token of appreciation of past service, but also as an encouragement and a challenge to continue in my work. This was of great value to my morale. It can probably be understood, and I readily admit, that in the first moments following the tragic happening at Lakehurst, which came so unexpectedly after hundreds of happy voyages, I felt a deep loss, and almost began to doubt whether the Zeppelin idea could still be carried on. The award of the Guggenheim Medal, therefore, in these hours of greatest sorrow, seemed to me like help from friends which rescued me from the deepest discouragement.

"It was immediately evident that a continuation of Zeppelin operations was out of the question with ships inflated with hydrogen; on this point, I am sure, I do not have to elaborate. We had of necessity to go to the use of the non-inflammable helium. The first problem was therefore: Is it possible to obtain sufficient quantities of helium? I am happy to be able to acknowledge here most gratefully that the President and Congress of the United States, in the generous spirit of their "good neighbor" policy and with great vision towards the future, initiated and enacted legislation which makes safe helium gas more readily available for the purpose of international commercial airship trans-

portation. Your Government's indication of its willingness to share the benefits of this safe gas, has given us the necessary fundamental and positive decision, which allows us to carry on.

"Immediately another problem arose, one of a technical nature: When using helium as lifting gas, would lighter-than-air be commercially economical? Produced in the modest quantities of today, helium is about ten times as expensive as hydrogen. Would therefore its use not be prohibitive? It was clear that the lavish squandering of an airship's lifting gas, as was the practice with the cheaper hydrogen, could no longer be indulged in. It would be necessary to some extent to modify our operating technique.

"It is a well-known fact that the system of so-called "water-recovery" is the deciding factor with which this problem can be solved. While in hydrogen operation, the weight of fuel consumed in the motors is balanced by deliberately valving or releasing a compensating amount of lifting gas, it will be necessary in helium operation, to create this balance by water ballast recovery from the exhaust gases. I should like to state here that our tests in Friedrichshafen have shown that without difficulty it is possible to recover a sufficient quantity of water ballast from the exhaust gases of the Diesel engines which we employ.

"With this, the deciding factor has been obtained; but additional steps must be taken to avoid other losses of helium. When using hydrogen, airships took off from the surface fully or nearly fully inflated. This, however, entailed an immediate loss of lifting gas through valving, until the necessary flying altitude had been reached. To fly over low mountain ranges, this altitude must be at least 1900 to 2300 feet, and it was therefore necessary to provide suitable measures for reaching such altitudes without expensive loss of gas. It is possible by pre-heating the lifting gas before the ascent, to rise with the ship not fully inflated; at the lower temperatures of flying altitudes, the pre-heated gas cools off rapidly to outside temperatures in flight, and the ship may reach the required flying altitude without appreciable loss of gas. Tests made in Friedrichshafen have shown that this problem of pre-heating also can easily be solved.

"The situation then is as follows: With these two means at our disposal, namely water recovery and pre-heating of the gas, it will be possible in the future to carry out oceanic voyages without losses of helium by valving. Except for losses through unavoidable incidents, helium should not be lost, except through unavoidable diffusion and in purification. These losses, however, are expected to be kept so low, that they should not exceed 10% of the total losses we have had in hydrogen operation. This would mean that helium operation essentially should not be higher in cost than hydrogen operation.

"This finding, however, is of the greatest importance for the future development of airships. It is self-evident that airship transportation can be maintained and survive only, if it is economical and self-supporting. One cannot keep it alive indefinitely with money out of the pockets of the tax payers; this is necessary and justified only during the first years of development. The ten demonstration round-trips of the *Hindenburg* in 1936, however, proved that with an average booking of 70 to 75 passengers at a rate only little above the average cost of a first cabin passage on an express steamer, it is possible to have self-supporting airship transportation. It should not be difficult to maintain bookings of 70 to 75 passengers, especially on future helium-filled airships which guarantee a maximum of safety. It is well-known that many travelers refrained from using the airship previously, because of its inflation with hydrogen.

"In conclusion, let me say that just as has been the case in comparable tragedies in other modes of transportation, the tragic *Hindenburg* catastrophe, terrible and deplorable as it was, has actually brought about tremendous progress in the safety of this modern means of transportation. Only now, with helium assured are we fully convinced and justified in advocating the Zeppelin airship as a means of transportation. I, for one, will continue to do so wholeheartedly, and I wish to thank you for the precious medal which will inspire me further.

"More than ever is it necessary today to work for everything that may bring peoples and nations closer to each other; and this means first of all the development of Commerce and transportation, which in the end—I am positively convinced—will finally triumph over all that which now separates peoples and nations in an atmosphere of Chauvinism."

This evening you are doing honor to Dr. Eckener as more than just a great aeronautical character; you are honoring a great personality as well. The epoch-making flight of Colonel Lindbergh was but the climax of years of toil and preparation, accumulation of knowledge and experience. Dr. Eckener's contribution to the field of aeronautics in 1936, likewise represented the fruits of many years of labor and devotion to a cause.

As a young journalist who first scoffed at airships, Hugo Eckener became attracted to the cause first through admiration for Count Zeppelin and then through studious realization of the real merits of the airship. Successively he went through many posts in the organization, always progressing and eventually succeeding to the mantle of old Count Zeppelin as the guiding cause in the development of the rigid airship. He has seen the airship cause prosper and suffer, but never become extinguished. In the lean years, even as Managing Director of the organization, Hugo Eckener couldn't afford even a modest European car but peddled his way about by bicycle. But never did he lose sight of his goal—transoceanic airship service.

Dr. Eckener had intended to retire from active service in the summer of 1937, satisfied that he had brought the airship itself to the point where personnel and material were ready to carry on and permit him to view its future development somewhat from the sidelines, as it were. But the tragic losses of his right bower, the late Captain Ernst Lehmann and other valuable pioneering personnel, have brought Dr. Eckener like a good soldier, back into harness again, with multitudinous duties on his broad shoulders once more. Aerial ambassador extraordinary and purveyor of good will, we shall indeed see more of Hugo Eckener and be glad often to welcome him back to these shores.

In closing, I wish to express my sincere thanks to Mr. Guggenheim and the Institute of Aeronautical Sciences for the honor of having been permitted to participate in relaying this justly earned award to my good friend, Dr. Hugo Eckener.

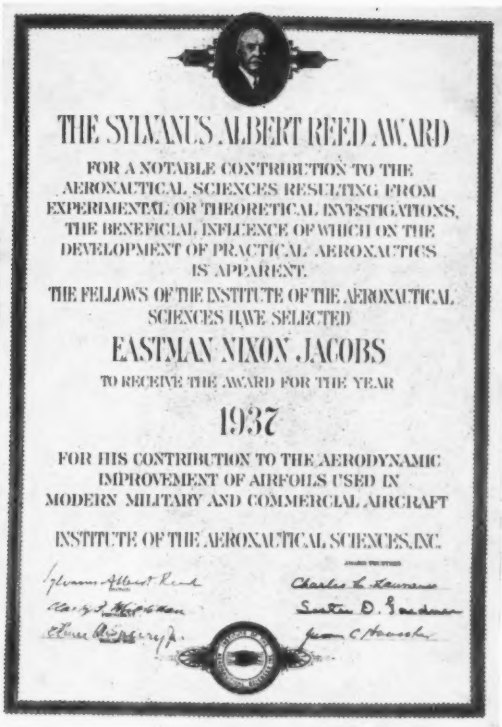
Mr. Guggenheim: I have a cable here from Dr. Eckener: *"On account of not quite satisfactory health, am unfortunately compelled to renounce personally attending the meeting. I beg to express by cable my appreciation of the great honor bestowed upon me by the awarding of the Daniel Guggenheim Medal and at the same time to express my warmest greetings and best wishes for further blessed and successful activities of the Institute of the Aeronautical Sciences. Signed, Eckener."*

The second honor to be bestowed is the Sylvanus Albert Reed Award. The recipient this year is one of the ablest members of the staff of the National Advisory Committee for Aeronautics. Nearly the entire Committee is here this evening to have the pleasure of seeing this award bestowed. We also wish that the Committee's Chairman, Dr. Ames, might be here, but only ill health prevents his presence.

I have a telegram from Dr. Ames that I would like to read to you: *"Congratulations to the Institute on the inauguration of the dignified program to honor the Wright brothers and to commemorate the birth of aviation. Congratulations to all who are being honored tonight. Am highly gratified at honors bestowed on members of our organization and particularly over recognition of Jacob's important contribution."*

And now it is my pleasure to call on my good friend, E. P. Warner, who is also a member of the National Advisory Committee for Aeronautics, who has been asked to bestow the Reed Award.

Eastman N. Jacobs



THE SYLVANUS ALBERT REED AWARD

FOR A NOTABLE CONTRIBUTION TO THE AERONAUTICAL SCIENCES RESULTING FROM EXPERIMENTAL OR THEORETICAL INVESTIGATIONS, THE BENEFICIAL INFLUENCE OF WHICH ON THE DEVELOPMENT OF PRACTICAL AERONAUTICS IS APPARENT.

THE FELLOWS OF THE INSTITUTE OF THE AERONAUTICAL SCIENCES HAVE SELECTED

EASTMAN NIXON JACOBS

TO RECEIVE THE AWARD FOR THE YEAR

1937

FOR HIS CONTRIBUTION TO THE AERODYNAMIC IMPROVEMENT OF AIRFOILS USED IN MODERN MILITARY AND COMMERCIAL AIRCRAFT

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

Presentation of the Sylvanus Albert Reed Award

Hon. Edward P. Warner: As December 17 approaches each year, the thoughts of each of us must turn to a bleak December day on the wind-swept Carolina Beach thirty-four years ago. To some of us, the great events of December 17, 1903, came as a matter of substantially contemporary knowledge. To some, they have come as a much later reading of history, but to each of us must have come at some time, the inclination to try to recapture the emotion of that day, to fancy himself a participant in the scene that took place at Kitty Hawk.

That was thirty-four years ago, years richly filled with events and now we come to Honors Night of the Institute of the Aeronautical Sciences.

For years beyond reckoning, groups of men have been gathering together, as we are gathered here tonight, and selecting those of their own number whom they would adorn with special distinction. We have always taken, I think, a particular satisfaction in our participation in any such selection, for in that well-worn statement, that in honoring him we honor ourselves, there is a profound truth.

Honor resides in the character of the organization by which honor is paid and I think that I have been sufficiently remote from the management of the affairs of this Institute in recent years to say what its officers would not say, that the Institute of the Aeronautical Sciences has attained in these recent years to a high place and a deserved recognition among the world's scientific bodies.

Honor resides in the manner of election, and the recipient of the Sylvanus Albert Reed Award is chosen by that most democratic and most rigorous of methods, election by the parliament of his peers, the seventy Fellows of the Institute.

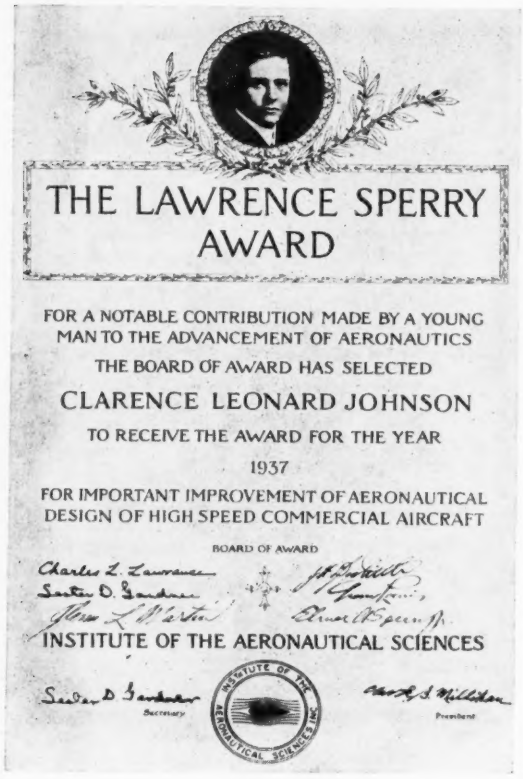
Honor resides in the tradition that cumulatively clusters about an award and we are making an addition tonight to a roster already illustrious, a roster already bright with names each of which recalls its own particular triumph of aeronautical progress.

Honor resides in the occasion of an award's founding and in the character of the achievement for which the award is made and in the character and in the services of him who is designated to receive it.

Of those matters, we can best speak here tonight as a collective whole. When Dr. Reed began his notable work, he had in his own mind and as his own initial contribution, a clear theory of what he thought might be accomplished. Of the processes by which the theory was developed and the obstacles surmounted, we all recall something of the history. But his experience must have left Dr. Reed with a profound sense of the value and the importance of a nice blending of theory and practice, and of the importance of never allowing either one to get too far out of step with the other.

Dr. Reed would have appreciated and admired the work that has been done by Mr. Jacobs, not merely for its superficial evident practical value, but for its underlying quality. He would have admired the skill with which mathematical arts have been used to fertilize the field of experiment. He would have admired the ingenuity with which new instrumental equipment has been developed and new techniques of research devised as the means for utilizing them arose. He would have admired, not less, but no more than those other and more preliminary factors, the final application which has left its mark upon practically every aircraft designed in the last three years and which has made the symbol 230-12 as well known in the aeronautical community as H_2O is among chemists. All that he would have appreciated, and we appreciate it here.

Still speaking of what I know the sponsor of the Reed Award would have felt, he would have appreciated, too, the fact that at the end of a day devoted to developing the means of increasing the standards of efficiency and of performance of aircraft, of power and capacity, still lying far beyond our present horizon, Mr. Jacobs has turned for relaxation to a fresh field of rather meagre


THE LAWRENCE SPERRY AWARD
FOR A NOTABLE CONTRIBUTION MADE BY A YOUNG MAN TO THE ADVANCEMENT OF AERONAUTICS
THE BOARD OF AWARD HAS SELECTED
CLARENCE LEONARD JOHNSON
TO RECEIVE THE AWARD FOR THE YEAR
1937
FOR IMPORTANT IMPROVEMENT OF AERONAUTICAL DESIGN OF HIGH SPEED COMMERCIAL AIRCRAFT
BOARD OF AWARD
INSTITUTE OF THE AERONAUTICAL SCIENCES
Secretary
President

quality and to an aircraft of rather meagre power, the product of his own hands and his own desire, and as his own builder, has gone into the air as his own pilot.

Eastman N. Jacobs, born in Colorado, graduate of the University of California, for twelve years a member of the staff of the National Advisory Committee for Aeronautics, Wright Medalist of the Society of Automotive Engineers in 1933, guest speaker of the Volta Foundation in 1935, tonight becomes recipient of the Sylvanus Albert Reed Award *"for his contribution to the aerodynamic improvement of airfoils used in military and commercial aircraft."*

Acceptance by Mr. Jacobs

Mr. Eastman N. Jacobs: Even granting some of the very flattering remarks made by the Honorable Edward P. Warner, I still remain a little mystified as to why you should have chosen me for this honor, but I can say very truthfully and literally and sincerely to all of you, my friends in the Institute of the Aeronautical Sciences, I cannot tell you how deeply grateful I am to you for this award at this particular time.

I know that in honoring others, we honor ourselves. I think Professor Warner suggested the investigation of airfoil sections in tunnels in the first place, so he could say that very honestly but I cannot dwell on all the people who have helped me with this work. It has certainly been a joint work and the National Advisory Committee for Aeronautics really deserves the credit.

Particularly, I want to emphasize the credit due Dr. Lewis for his constant push, particularly through the early phases of investigation.

I should also like to speak about those who do not get the credit. The people who do not get the credit for this are certain aeronautical engineers. They were the ones who said we were wasting our time investigating wing profiles and their drag because the wing profile drag, according to them, was an insignificant part of the entire airplane drag and we couldn't do anything about it anyway. Well, I am gratified to say that I think we have reached the stage where all of us are agreed that this is not true. The wing profile drag now is a very important item. We held a very interesting meeting this afternoon in which we had enthusiastic listeners and discussers concentrating on this one particular problem of further reducing the wing profile drag. Thank you.

Clarence L. Johnson

Mr. Guggenheim: We now come to the newest of the awards. This one was established in memory of that genius of early aviation, Lawrence Sperry. Last year, it was presented for the first time. This particular award is to encourage young men in aviation and is given for achievements of men under thirty. You will recognize that the various awards made tonight each have their own sphere. Their fields are quite separate.

Lawrence Sperry would have been happy to know that his memorial, as endowed by his brothers and his sister, was intended to encourage young men in aviation. He was a youth when he died. He needed no encouragement. He was full of energy, ambition, and ability. He built his first airplane in a bedroom and it was better than most of the backyard airplanes of today. He flew it himself successfully. He knew no such thing as fear and he developed a skill and technique that was really amazing. Most of the early aeronautical pioneers realize what a great loss it was to aviation when he died.

It has been with great reluctance that we have been able to persuade Elmer Sperry to present the award tonight. He inherits the modesty of his great father. Elmer Sperry, Jr. carries on the fine tradition of his family for research and enterprise.

Presentation of The Lawrence Sperry Award

Mr. Elmer A. Sperry, Jr.: When I look around, I see that there are quite a few Sperrys here, so may I say in behalf of the Sperry family, that the Lawrence Sperry Award was established last year at the suggestion of the Institute of the Aeronautical Sciences and that it is most gratifying to hear from many of Lawrence's old friends, both here and abroad, that this act on the part of the Institute of the Aeronautical Sciences is a most suitable tribute to his memory.

This year, the Committee, consisting of Grover Loening, Glenn L. Martin, Charles L. Lawrance, James Doolittle, Lester Gardner, and myself, selected as the recipient of the Lawrence Sperry Award, Clarence L. Johnson, *"for important improvement of aeronautical design of high speed commercial aircraft."*

Mr. Johnson is 27 years old. He was graduated from the University of Michigan in 1933. He was a football player and on the football team. Later, he did graduate work at the University of Michigan. The Lockheed Aircraft Corporation sent a model to be tested in the wind tunnel of Michigan. Mr. Johnson made the test, wrote the report, and sent it back to the Lockheed Corporation. They couldn't understand a word of it so they asked him to come and tell them what it was all about. He went and soon after joined their Research Division. He has been in charge of research work and test work on the transport planes developed by Lockheed.

I am sure, Mr. Johnson, that Lawrence would have been as happy as I am to present you with this check and with this certificate of award. I hope that this recognition of your work by the Institute of the Aeronautical Sciences will be a stimulus to you in achieving still greater accomplishments.

Acceptance by Mr. Johnson

Mr. Clarence L. Johnson: It was a very useful gag, you might say, to write a report that nobody could understand. I have tried to do it ever since. In many respects, I hope I have succeeded.

I accept this award as a tribute to Lawrence Sperry, who built the first airplane in a bedroom. Mr. Sperry was very young, very enthusiastic, and he set an example for all of us to follow. I thank you.

Mr. Guggenheim: For the presentation of the other Institute honors, I shall now call on Dr. Millikan.

Fellows for 1937

Dr. Millikan: In accordance with the By-laws of the Institute, the Fellows each year elect ten new members to fellowship. This year the ten were chosen by ballot from an initial list of sixty-seven nominees. The election was concluded only last week so that many of the newly elected Fellows could not arrange to be present to receive their certificates in person.

We are very happy to be able to announce the names of all the new Fellows and to hand their certificates of Fellowship to those who were able to be here: B. C. Boulton for eminent contributions in airplane design, Commander C. E. Rosendahl for leadership in the development of American lighter-than-air aircraft, and P. B. Taylor for your part in the development of modern American airplane engines.

The newly elected Fellows who were unable to be here are Lieutenant Commander Ralph S. Barnaby of the United States Navy, Dr. Karl T. Compton, President of the Massachusetts Institute of Technology, Professor A. V. de Forest of the Massachusetts Institute of Technology, Professor E. P. Lesley of Stanford University, A. A. Priester of the Pan-American Airways, Professor C.-G. Rossby of the Massachusetts Institute of Technology, and Dr. L. B. Tuckerman of the National Bureau of Standards.

Honorary Members for 1937

One pleasant duty remains, the presentation of the certificates of Honorary Membership in the Institute. The Honorary Members are elected each year by your Council in recognition of their services to aviation. I will not attempt any extended remarks in introducing these distinguished gentlemen in handing them their certificates, since their careers and their achievements are known to everyone connected with aeronautics.

Dr. Lyman J. Briggs, Director of the National Bureau of Standards.

Rear Admiral A. B. Cook, Chief of the Bureau of Aeronautics of the United States Navy Department.

Fred D. Fagg, Jr., Director of Air Commerce of the Department of Commerce.

Dr. W. R. Gregg, Chief of the United States Weather Bureau.

Hon. Harry F. Guggenheim, member of the National Advisory Committee for Aeronautics.

Dr. George W. Lewis, Director of Research of the National Advisory Committee for Aeronautics.

Major General O. Westover, Chief of the Air Corps of the War Department.

H. E. Wimperis, President of the Royal Aeronautical Society. I am going to ask professor Jones if he will deliver this certificate to Mr. Wimperis on his return.

Mr. Guggenheim: To close this memorable evening, we are about to hear from the dean of any aeronautical scientific gathering, our one and only Dr. Durand.

If I should begin to tell you of the many accomplishments that fill the magnificent career of Dr. Durand, I should not only keep you here all night, but I should not enjoy the friendship that I hope I now have with Dr. Durand. I have Dr. Durand at a disadvantage tonight. But I will not embarrass him. I will only tell him how deeply he is beloved by all of his colleagues and ask him if he will be so kind as to give his address.

The Wright Brothers

Dr. William F. Durand: I am glad of the opportunity to speak some few words in signalization of this occasion, which links together the events of today, here in New York City, and the profoundly historic event which occurred on the North Carolina coast thirty-four years ago.

The story of the conquest of the air by the Wright brothers, brought to its fruition on that occasion, is too well known to you to need repetition, but there are some aspects of that long and patient search to which more than a passing thought may perhaps be given.

By their own words, it would appear that their interest in human flight traces back to 1878 and to the antics of a toy helicopter which their father had brought back and given to them as boys on that occasion. Who can say that the results of later years did not trace back to that incident, as a little seed planted a quarter of a century earlier and brought to flower in the epoch-making achievement of 1903? In any case, we may well believe that the effect of this early incident was never lost, and when as young men they came to know of the world of Lilienthal, Pilcher, and especially Chanute, who was their neighbor, this early interest became quickened into an absorbing passion.

In common with Lilienthal, Pilcher, and Chanute, they believed that the way to human flight lay through experience with the glider. Of the three basic problems of flight, namely sustenation, propulsion, and control, they believed the last to be on the whole the most difficult and the one calling for the first specialized study.

Wilbur Wright has been quoted on some occasion as having said that there were two ways in which to learn to ride a fractious horse; one was to ride the horse and to find out by experience the best manner of conquering and ruling his jumps and jerks and turns and tricks. The other was to sit on a fence nearby and see him go through these maneuvers and then retire peacefully and quietly and try to figure out how to meet them. He remarked further that the latter was much the safer way but the former was likely to produce the best rider.

And so, with an eye to the immediate purpose of achieving experience in the air, they began that series of experiments on the Kill Devil Hills near Kitty Hawk, North Carolina, extending from 1900 through to the close of 1903, first with gliders and finally with their engine-powered machine with the crowning result which we now know.

To me, these pioneer years of study and continued progress for the goal in view, have in their outstanding features, all that stood out as an example of faithfulness to the highest ideals of scientific research, the grand strategy employed, the appeal to experience and the continued change and improvement based on the results of such experience, the study of such basic data and information as was then available, and the early appeal to the wind tunnel for

the extension and creation of such data. The patience, the persistence, the faith in ultimate success, the skill employed in meeting unexpected and discouraging obstacles and difficulties—these were all manifest in the highest degree.

Early Glider Experiments

You will recall that three successive gliders were built, of continuously enlarging sizes, each one embodying the results of experience with the preceding. Then followed the engine-powered machine expressing in its form, proportions, and mode of control, the integration of the experience with the preceding forms of gliders.

Thus, the three years of experience in riding a glider under all kinds of atmospheric conditions, led to the final results of 1903.

It is of interest to note, as they did, that in the five years of Lilienthal's work with gliders, he was able to realize only something like five hours in the air. Impressed with all too short period of actual gliding time, they held before themselves the ideal of much longer periods, of many long hours in the air, during which every trick and turn of this fractious horse might be studied and mastered. To this end, as you will perhaps remember, they had hoped to use a glider at least in part as a form of man-carrying kite sustained in an up-sloping current of air, along one of the sand dunes comprising the Kill Devil Hills, and thus giving far longer periods of time for the study of control than would be possible with free glides.

December 17, 1903

These hopes, as we know, failed of full realization and in fact they returned from the experiments of 1900 with only a few minutes of actual flying in the air. This was followed, however, in the later years, by longer and longer flights with increasing time in the air and while no actual record of glider flights was kept, the number was certainly in the hundreds, perhaps between seven or eight hundred and a thousand, and all leading up to the climax of December 17, 1903, the day on which was demonstrated not only the possibility but the practicability of human flight in a self-powered, man-controlled machine.

It is that achievement which we celebrate on this occasion—the release of man from a two-dimension world as to his movement, and the opening up of a third dimension by way of flight in the air.

I deem it peculiarly appropriate, as the inaugurating speaker of this Wright Brothers' Lecture, that a distinguished representative of our elder sister society in Great Britain has been chosen and that he has told us of some of the recent developments in matters relating to our understanding of the conditions of flight leading to ever increasing refinement in detail, because after all, this is only carrying along the same lines and in the same spirit, so admirably set before us as an example, the work of the Wright brothers, the third of a century and more ago.

Of these two brothers Wright, one, as we know, has passed on to his reward, and surely with the encomium, "Well done, good and faithful servant." The other one, Orville Wright, we are permitted to have here with us today and to make more perfect the conditions of this occasion. I know that I only echo your own thought in wishing him to be with us for many years that we may enjoy his friendship and profit by his wisdom and counsel.

Congratulatory Telegram from R. Ae. S.

Mr. Guggenehim: In closing this memorable evening, I cannot do better than repeat what I said before, that I believe that the Institute has originated today a unique form of anniversary commemoration which is blessed with a distinction hitherto unknown in the casual celebrations of this day. I can think of no better compliment both to ourselves and to the Royal Aeronautical Society than to read in closing this cable which has come from them: *"The council and members of the Royal Aeronautical Society send to Council and members of the Institute of the Aeronautical Sciences, their every good wish for the success of the first Wright Brothers' Lecture by their joint distinguished Fellow, Melvill Jones. The happy thought which inspired its inauguration will link still more closely the Institute and the Society which have the science of aeronautics so much at heart, and in their most important lectures, pay lasting tribute to those great names, Wilbur and Orville Wright. Signed, Pritchard, Secretary."*

Among the five hundred members and guests were the following: B. W. Ainsworth, J. S. Allard, John H. R. Arms, W. J. Austin, Preston R. Bassett, Vincent Bendix, H. A. Berliner, P. E. Bewshea, Enea Bossi, S. S. Bradley, A. R. Brooks, Jean Brun, W. A. M. Burden, W. Starling Burgess, Lt. Comdr. S. Calloway, J. E. M. Carvell, Reed M. Chambers, George Chapline, C. H. Chatfield, Charles H. Colvin, J. Carroll Cone, Duncan B. Cox, Luis de Florez, J. P. Dods, Dr. H. L. Dryden, Shepard Dudley, Wm. R. Enyart, Lloyd Espenchied, Sherman M. Fairchild, H. A. Franchimont, L. D. Gardner. A. J. Gariepy, W. F. Gibbs, Corrington Gill, B. Allison Gillies, R. E. Gillmor, M. B. Gordon, B. B. Gragg, L. R. Grumman, J. M. Gwinn, Jr., A. J. Hamon, Capt. S. S. Hanks, Col. Harold E. Hartney, J. T. Hartson, Beckwith Havens, P. E. Hemke, Gerard P. Herrick, Charles F. Horner, Dr. L. M. Hull, Dr. J. C. Hunsaker, Major C. S. Johnson, S. Paul Johnston, C. S. Jones, Ernest Jones, Temple N. Joyce, Dr. J. H. Kimball, Prof. Alexander Klemin, Paul Kollsman, Colonel F. P. Lahm, R. P. Lansing, Robert B. Lea, Jerome Lederer, Dr. G. W. Lewis, Al Lodwick, R. R. Loening, C. T. Ludington, E. C. Lynch, James A. McDonnell, A. B. McMullen, George Mead, H. L. Mingos, T. A. Morgan, G. F. Myers, R. E. Nicoll, Arthur Nutt, E. D. Osborn, Leonard Outhwaite, Lew R. Palmer, C. G. Peterson, H. H. Platt, Robert C. Platt, Col. E. J. W. Ragsdale, Col. J. D. Reardon, H. J. E. Reid, W. A. Reichel, Colonel E. V. Rickenbacker, W. C. Rockefeller, F. F. Russell, F. H. Russell, John A. Sanborn, Howard A. Scholle, Prof. R. H. Spaulding, Edward G. Sperry, I. I. Sikorsky, Professor E. A. Stalker, George B. Swaine, J. B. Taylor, Jr., H. V. Thaden, J. T. Trippe, Guy Vaughan, John F. Victory, Fr. von Boetticher, F. W. von Meister, J. A. C. Warner, Comdr. W. W. Webster, Howard S. Welch, Comdr. R. D. Weyerbacher, George S. Wheat, E. Burke Wilford, Gill Robb Wilson, E. E. Wilson, Alfred L. Wolf, Dr. B. M. Woods, Orville Wright, S. J. Zand, and F. W. Zelcer.

A Test Stand for the Investigation of Gust Effects[1]

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(Received October 27, 1937)

Introduction

THE test stand of the Daniel Guggenheim Airship Institute for the study of gust effects, described in the following, was built in 1934. It was designed to duplicate the case of an aircraft encountering a gust of such sharpness that the air forces under investigation are developed before a change in the flight path or attitude of the aircraft occurs. This condition appeared to be of particular interest for two reasons:

(1) The aerodynamic forces caused by gusts, to the extent that they have been investigated, have never been checked experimentally.[2] Some types of such forces, *e.g.*, the gust forces on finite-span wings, have never even been treated theoretically.

(2) It is probable that sudden gusts create severe inner stresses on large aircraft without or before a perceptible change in the flight path.

The treatment of the problem of the air forces brought about by the combination of primary gust loads and secondary loads caused by an initial disturbance of flight direction and attitude of the aircraft under the influence of a gust, though tedious, is at least possible by theoretical computation, assuming that the primary forces are known.

In order to check such computations for airships, the Daniel Guggenheim Airship Institute has undertaken the construction of a water tank, in which the movement of airships under the influence of an artificial gust will be studied under conditions kinematically and dynamically similar to full-size conditions. However, these tests will have to be made at very low Reynolds Numbers. This test stand will be similar in some ways to that used by the National Advisory Committee for Aeronautics for the testing of gust effects on airplanes, but the heavier medium will make it possible to provide dynamic similarity on airship models, which must be equal in weight to the volume of the displaced medium.

Description of Gust Tunnel

The test stand for sudden gusts makes use of the whirling arm of the Institute,[3] to which a vertical wind tunnel has been added. A model mounted at the end of the 32-ft. arm, turning in a horizontal plane about ten ft. above the floor level, is made to pass through the open jet of this tunnel, which has a cross-section 15 ft. × 16 ft. (see Figs. 1 and 2). The horizontal velocity of the model can be varied between 5 m.p.h. and 160 m.p.h. The airship models used for tests up to now were about ten or twelve ft. in length, representing $^1/_{75}$-scale models of ships of the approximate size of the *Macon* or *Hindenburg*.

The vertical wind tunnel is driven by a 4-speed a.c. motor, giving four steps of velocities between 13 and 35 ft. per sec. No attempt has been made to obtain a high uniformity of velocity in one cross-section of the jet or to reduce turbulence. The latter, although unquestionably large, due to the lack of a diffusor reduction, was not considered of primary importance, because the resultant air velocity relative to the model is in almost all cases several times the wind-tunnel speed, and also because the turbulence is not a very important factor in the phenomenon under investigation. The distribution of the vertical velocity in the artificial gust met by the model is shown in Fig. 3. The "gust" is always composed of the two "transition zones," at the gust entrance and exit, and of the "gust center," having approximately constant velocity. This "gust center" is about 15 ft. in length along the model's path. As far as the "gust center" is concerned, it was thought best to correct the test results for the lack in uniformity whenever such a correction is warranted. The "transition zones" are the zones in which the jet velocity decreases from the full value at the "center" to zero. The velocity distribution here is necessarily highly turbulent. The average distribution measured with a pitot tube is in good agreement with that expected from theoretical computations for jet limits. The width of the transition zone is directly proportional to the distance of the cross-section from the beginning of the open jet, unless special adjustments are made. Within certain limits, this width can be easily adjusted by shortening the open length of the jet by adding wall sections above the jet opening. This shortens the free jet length under the model's path and thereby narrows and makes steeper the transition zone and provides a sharper gust. Wider gust transition zones, *i.e.*, "milder gusts," could be obtained by means of suitable vanes in the jet.

Comparison of Gust Tunnel with Atmospheric Conditions

A word may be said about the conditions provided by this setup as compared to the actual conditions encountered by an airship in flight. Geometric similarity between the flow picture about the model and that about the full-scale airship is realized if a gust of the same magnitude, but with a transition zone 75 times greater is encountered by the airship. With the $^1/_{75}$-scale airship model, the above transition widths

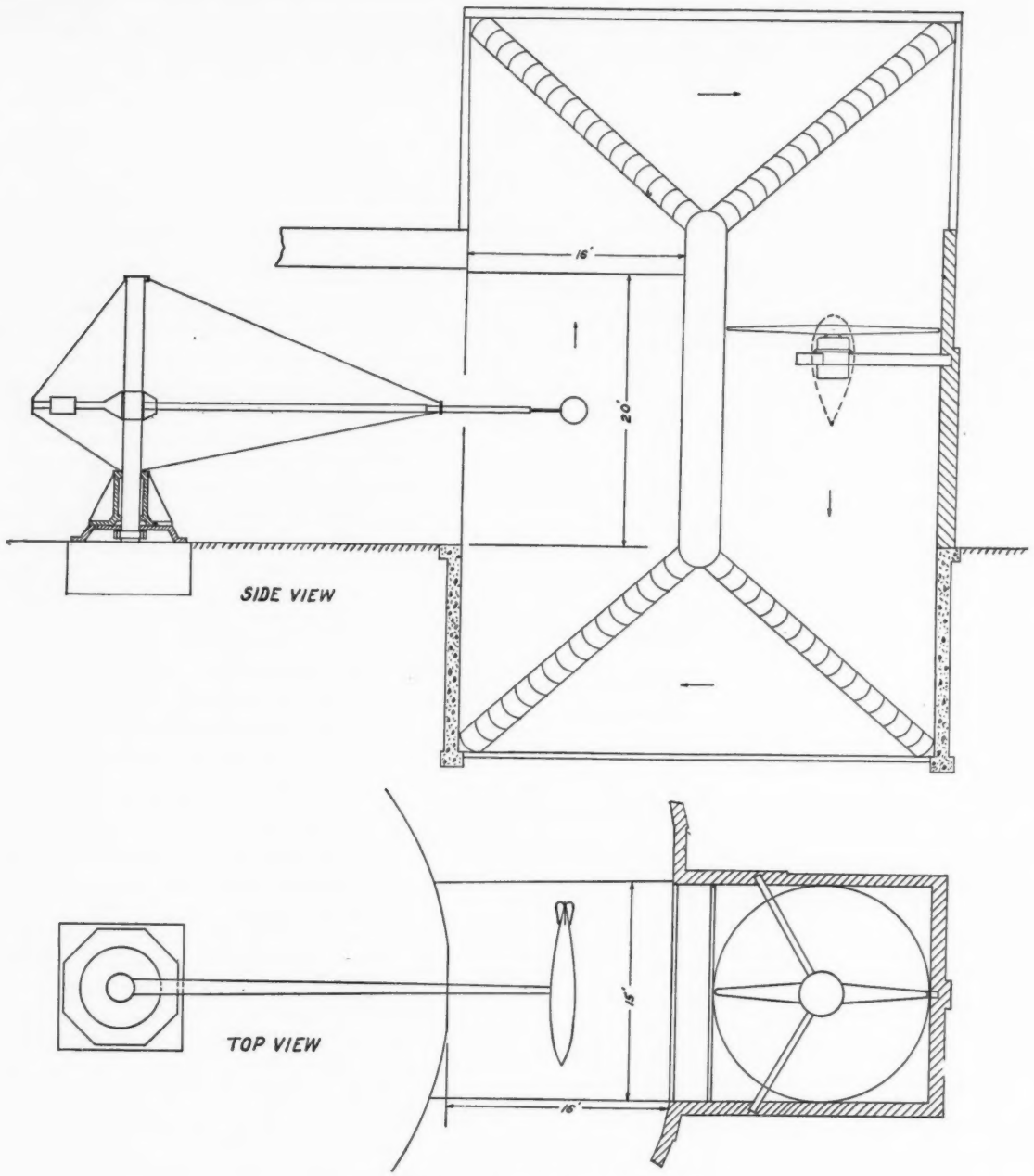

FIG. 1. Diagrammatic drawing of gust tunnel.

correspond to full-scale transition widths of 37.5 and 57 meters, respectively.

With regard to the question of the severity of the gusts encountered in the atmosphere, some data obtained at the Guggenheim Airship Institute are immediately applicable.[4] Records of wind velocity and direction were taken, especially during storm conditions, and analyzed for the cross-wind components existing. These records were taken at the top of a 50-ft. tower on the Institute building. The instruments were about 100 ft. above the ground.

Fig. 4 represents records of wind velocity and direction taken over a period of five minutes during the passage of a reasonably severe cold front. From these records the cross-wind velocities were calculated. The cross velocity at any point is the velocity multiplied by the sine of the angular deviation from the mean wind direction. The natural frequency of the wind vane was around one per second, hence it was necessary to restrict the analysis to mean values over at least one second. The solid curve represents the one second mean values of the cross velocities. The velocity of

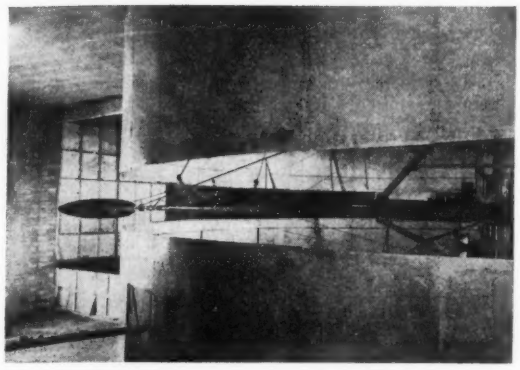

FIG. 2. Airship model, 12 feet long, entering gust tunnel.

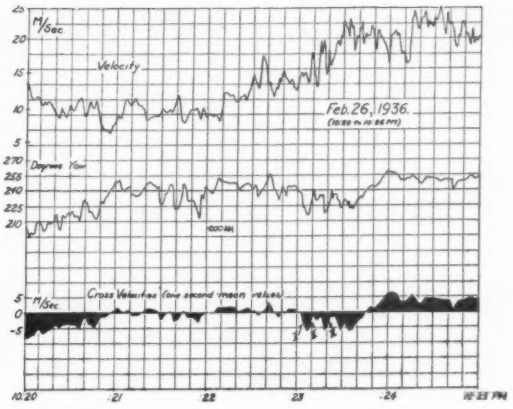

FIG. 4. Records of atmospheric gustiness.

movement of the cold front was 12 m. per sec., so that substituting a length scale for the time scale, 200 meters = 16.5 seconds. At I we have a 6 m. per sec. acceleration in cross velocity in 4 seconds, or 48 meters. At II and III the acceleration is 4.5 m. per sec. in 2 seconds, or 24 meters. These are the most severe accelerations shown on this record. The cross velocities shown are in the horizontal plane. They will therefore have the same effect on side forces experienced by an airship as will vertical velocities on the vertical forces.

Fig. 5 represents another set of such records, taken during snow squalls accompanying a cold front. The velocity of movement of the cold front was 17 m. per sec. On this record the most severe cross-velocity change is 8 m. per sec. in 37 meters at IV. At V the acceleration is 5.7 m. per sec. in 42 meters.

Fig. 6 represents a much more severe case—that of a local thunderstorm. The velocity of movement of the storm was not known, but the accelerations in the cross velocity with respect to the time are considerably higher than those measured in the other two cases. At VI the acceleration is 7.4 m. per sec. in 2.5 seconds. At VII the acceleration is 9.4 m. per sec. in 4.2 seconds. At VIII the acceleration is 9.4 m. per sec. in 2 seconds. At IX the acceleration is 10.1 m. per sec. in 7.0 seconds. Table 1 gives the accelerations from these records.

It may be seen from the table that the gradients represented by the experimental setup are not as high as the highest values observed in the atmosphere. Those taken during the thunderstorm, however, represent an extreme type of disturbance, and one which an airship can and should avoid.

RECORDING APPARATUS

Two sets of apparatus have so far been used for the measurement of gust effects. Hot wires have been used for the measurement of the flow around the model while it passes through the gust. The hot-wire anemometer for the measurement of absolute velocities is

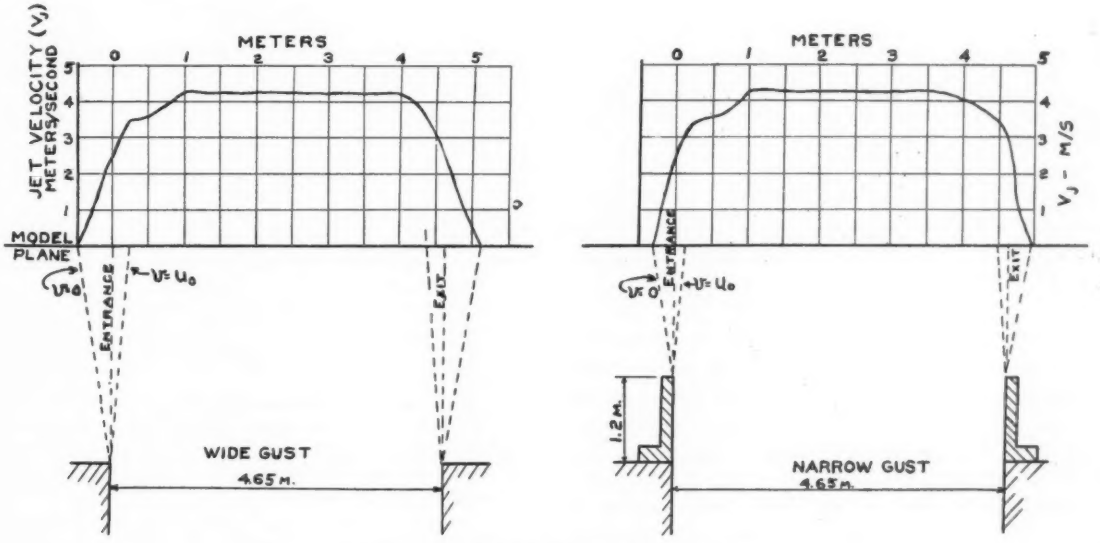

FIG. 3. Velocity distribution in gust tunnel.

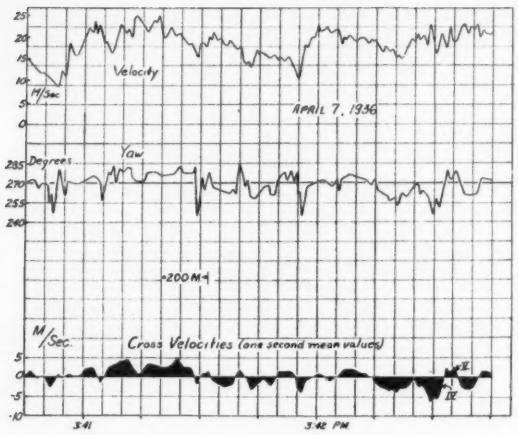

FIG. 5. Records of atmospheric gustiness.

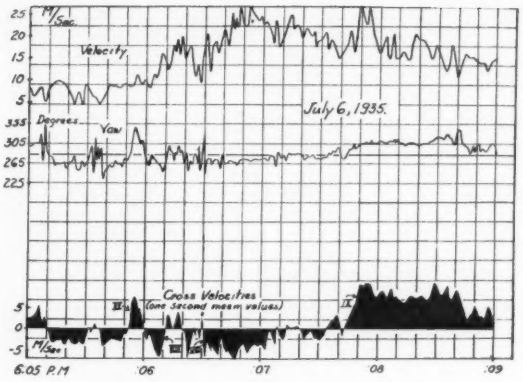

FIG. 6. Records of atmospheric gustiness.

TABLE 1

Record	Δv	Δt	C	Δx	$\Delta v/\Delta x$
I	6.0	4.0	12	48	.13
II	4.5	2.0	12	24	.19
III	4.5	2.0	12	24	.19
IV	8.0	2.2	17	37	.22
V	5.7	2.5	17	42	.14
VI	7.4	2.5	12*	30	.25
VII	9.4	4.2	12*	50	.19
VIII	9.4	2.0	12*	24	.39
IX	10.1	7.0	12*	84	.12

* Assumed values of C, the speed of movement of the storm.

well known and requires no further description. An instrument developed at this Institute has been used for the measurement of direction changes. This instrument and some hot-wire tests will be described in another paper.

For force measurements, the method of registering wire extensions by means of a diamond scratching on a glass cylinder is being used.[5] The complete model, or those parts of it on which acting forces are to be registered, is suspended on as many pairs of wires as there are force components to be measured. The extension of these wires is transmitted by means of suitable lever systems to a diamond point moving on the surface of the glass cylinder. The record gives the forces in the axial direction and the time along the circumference, which results from the turning of the glass cylinder. The records are then magnified and read off microscopically.

Various such suspension systems have been used successfully. A description of one of them, for the measurement of lift and pitching moment acting on an airship, has already been published.[6] In another test, the fin of an airship was held against the hull by means of three pairs of wires, giving three components of the normal force on the fin in such a way that the force, the pitching moment, and the moment about the fin

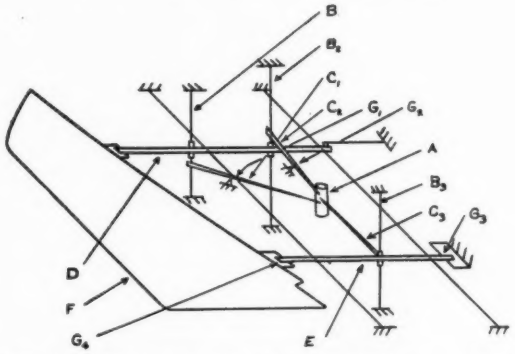

FIG. 7. Schematic drawing of suspension for measuring forces on airship fins during passage through gust. A, glass cylinder; $B_{1,2,3,}$, lift wires; $C_{1,2,3,}$, levers carrying diamond points; D, front spar; E, rear spar; F, fin; $G_{1,2,3,}$, hinge points

root could be determined. Fig. 7 shows this arrangement.

REFERENCES

[1] Partly included in a paper presented by Dr. A. M. Kuethe at the Annual Meeting of the I. Ae. S., January, 1937. See reviews of meeting: Klemin, Alexander, *The I. Ae. S. Annual Meeting*, Aircraft Engineering, Vol. 19, No. 97, pp. 69–72, March, 1937; Klemin, Alexander, and Watter, Michael, *Review of the Annual Meeting of the Institute of Aeronautical Sciences*, Aero Digest, Vol. 30, No. 3, pp. 24 and ff., March, 1937.

[2] Since the construction of the gust test stand described here, one such investigation has come to the attention of the author. See Küssner, H. G., *Untersuchung der Bewegung einer Platte beim Eintritt in eine Strahlgrenze*, Luftfahrtforschung, Vol. 13, No. 12, December, 1936.

[3] Troller, Th., *The New Whirling Arm of the Daniel Guggenheim Airship Institute*, Journal of the Aeronautical Sciences, Vol. 1, No. 4, pp. 195–197, October, 1934.

[4] The investigation was undertaken with the cooperation of the Bureau of Aeronautics of the Navy Department and the U. S. Weather Bureau. The majority of the observations were made by Dr. A. M. Kuethe.

[5] The method is described by Pabst, W., *Aufzeichnung schneller Schwingungen nach dem Ritzverfahren*, Jahrb. D.V.L., 1930. The author acknowledges with thanks various suggestions made by members of the staff of the D.V.L. regarding the execution of the method.

[6] Troller, Th., *Aerodynamic Research at the Daniel Guggenheim Airship Institute*, Daniel Guggenheim Airship Institute Publ. No. 3, 1935.

Exchanges

The Institute exchanges the Journal with many other aeronautical periodicals. They are kept on file at the Skyport in Rockefeller Center, New York City, where members may read them. As readers of the Journal may wish to subscribe to some of them, a list of these periodicals with their addresses is published here. Information regarding subscription prices may be secured from the Secretary of the Institute.

Aero, Maneesikatu 2, Helsingfors, Finland.

Aero Digest, 515 Madison Ave., New York City.

Aeronautica Argentina, Velez Sarsfield 57, Cordoba, Argentina.

L'Aéronautique, 55 Quai des Grands-Augustins, Paris, France.

L'Aérophile, 7 Rue Sainte-Lazare, Paris, France.

The Aeroplane, 175 Piccadilly, London, W.1, England.

L'Aerotecnica, Via delle Coppelle 35, Rome, Italy.

Les Ailes, 77 Boulevard Malesherbes, Paris, France.

Aircraft Engineering, 2 Bloomsbury Place, London, E.C.1, England.

Air Law Review, Washington Square East, New York City.

American Aviation, Earle Building, Washington, D. C.

Asas, Caixa Postal 1967, Rio de Janeiro, Brazil.

Astronautics, American Rocket Society, 31 West 86th Street, New York, N. Y.

Aviation, 330 West 42nd St., New York City.

L'Aviazione, Corso Umberto 504, Rome, Italy.

Boletin de Aeronautica Civil, Calle Azcuenga 923, Buenos Aires, Argentina.

Bulletin du Service Technique de l'Aéronautique, 72 Chaussee de Waterloo, Rhode-Saint-Genese, Belgium.

Bulletin of the American Meteorological Society, Blue Hill Observatory, Milton, Massachusetts.

Bulletin Officiel du R.A.A., 6, Rue du Mezieres, Paris (6), France.

Bulletin Technique du Bureau Veritas, 31 Rue Henri-Rochfort, Paris (17), France.

Canadian Aviation, Journal Building, Ottawa, Canada.

Contact, Fort Lee, N. J.

Current Titles from Engineering Journals, 928 Broadway, New York, N. Y.

Deutsche Luftwacht, Schoeneberger Ufer 46, Berlin W35, Germany.

Der Deutsche Sportflieger, Peterssteinweg 19, Leipzig C1, Germany.

Les Fiches Aéronautiques, 6 Rue Galilee, Paris, France.

Flight, Dorset House, Stamford St., London, S.E.1, England.

Flugwesen, Konviktska 22, Prague 1, Czechoslovakia.

Indian Aviation, P. O. Box 2361, Calcutta, India.

Journal of Air Law, Northwestern University, Chicago.

Journal of the Institute of Engineers, Australia, Science House, Gloucester and Essex Sts., Sydney, N. S. W., Australia.

Journal of Research of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Journal of the Royal Aeronautical Society, 7 Albemarle St., Piccadilly, London, W.1, England.

Journal of Scientific Instruments, 1 Lowther Gardens, Exhibition Rd., London, S.W.7, England.

Journal of the Society of Automotive Engineers, 29 West 39th St., New York City.

Letectvi, Celetna 13, Praha I, Czechoslovakia.

Luftfahrt-Forschung, Verlag Oldenbourg, Munich 1, Germany.

Die Luftreise, Lindenstr. 35, Berlin SW68, Germany.

Luftfahrt-Literaturschau, Z.W.B. bei der D.V.L., Berlin-Adlershof, Germany.

Model Airplane News, 551 Fifth Avenue, New York City.

Model Aviation, The American Academy for Model Aeronautics, 1733 RCA Building, Rockefeller Center, New York, N. Y.

Monthly Weather Review, U. S. Dept. of Agriculture, Washington, D. C.

Motor and Flying, 24 Bond St., Sydney, N. S. W., Australia.

National Aeronautic Magazine, Dupont Circle, Washington, D. C.

Official Aviation Guide, 608 S. Dearborn St., Chicago, Illinois.

The Pilot, Grand Central Air Terminal, Glendale, California.

Il Politecnico, Via Spiga 32, Milan (2/7), Italy.

Popular Aviation, 608 S. Dearborn St., Chicago, Illinois.

Proceedings of Institute of Radio Engineers, 330 W. 42nd St., New York City.

Publications Scientifiques et Techniques du Ministère de l'Air, 55 Quai des Grands-Augustins, Paris, France.

Review of Scientific Instruments, 175 Fifth Ave., New York City.

Revue de l'Armée de l'Air, 55 Quai des Grands-Augustins, Paris, France.

Revue du Ministère de l'Air, 71 Avenue des Champs-Elysees, Paris, (8), France.

Rivista Aeronautica, Ministero dell'Aeronautica, Rome, Italy.

The Royal Air Force Quarterly, Gale & Polden Ltd., 2 Amen Corner, London, E.C.4, England.

Schweizer Aero-Revue Suisse, Gubelhangstrasse 22, Zürich-Oerlikon, Switzerland.

Soaring, 1614 Delaware Ave., Wilmington, Del.

Southern Flight, Ledger Building, Fort Worth, Texas.

Sportsman Pilot, 515 Madison Ave., New York City.

Technical News Bulletin of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Techniczne Nowosci Lotnicze, Czerwonego Kryza 21/23 m.6, Warsaw, Poland.

Technika Vosdushnogo Flota, U1. Radio 16, Moscow 16, U. S. S. R.

La Technique Aéronautique, 2 Rue Blanche, Paris (9), France.

U. S. Air Services, Transportation Building, Washington, D. C.

Western Flying, 420 S. San Pedro St., Los Angeles, California.

Wirtschaft Technik Verkehr, Alte Jakobstr. 148/155, Berlin, SW68, Germany.

Zeitschrift für angewandte Mathematik und Mechanik, Kulmstr. 1, Dresden A24, Germany.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

Calculation of a Helicoidal Fan in a Tube. A. Toniolo. Geometric characteristics are calculated for the generic case of many propellers and counter propellers placed in series as well as for the case of counter rotating propellers. Efficiency is also calculated and the influence of various factors on efficiency is discussed, including efficiency of profile adopted, operation ratio, thrust coefficient, degree of partialization, and number and arrangement of propellers and counter propellers. L'Aerotecnica, August–September, 1937, pages 736–750, 5 illus., 24 equations.

The Private Laboratory. M. Victor. Necessity for each French aircraft firm to have its own wind tunnels just as it has laboratories for testing materials. Types are suggested. Les Ailes, October 21, 1937, page 7.

Investigation of Induced Rotational-Bending Wing Oscillations in the Wind Tunnel. H. Voigt. Theory of wing oscillations with degrees of freedom of wing bending and wing rotation was checked experimentally. A wing was suspended between two lateral blocks in a wind tunnel in such a manner that vertical oscillations (bending oscillations) as well as rotational oscillations around any transverse axis could be carried out by the wing. All parameters of the springing and the masses were variable. The negligibly low natural damping of the system could be artificially increased and oscillations were recorded on a highly magnified scale. Critical velocities determined experimentally fully conform with those computed according to the Wagner and Kuessner theories, within the degree of accuracy of measurement and calculation. An extremely narrow wing without lateral walls (three-dimensional problem) yielded the same oscillations as that with lateral walls (two-dimensional problem). DVL report. Luftfahrtforschung, September 20, 1937, pages 427–433, 15 illus., 1 table.

The National Physical Laboratory. Turbulence, fluid motion, visualization of airflow, propellers, autogiro theory, vane anemometer, and flutter. Progress in research being carried on in the Aerodynamics Department on these subjects. Engineering, November 5, 1937, pages 504–506, 2 illus.

Aircraft Design

An Aerodynamic Novelty. Delta F compound-airfoil aircraft now under construction has a wing of normal aspect ratio with an outrigged tail unit connected to it by two additional surfaces, termed "side wings," built around the tail booms. Research has shown that this rectilinear form of annular wing induces a particular form of vortex distribution and vortex control giving high-efficiency characteristics despite the low aspect ratio of the members. It also induces an unorthodox aerodynamic load distribution which permits fullest advantage to be taken of spanwise static loading, making for a very light structure. Long description. Flight, November 18, 1937, pages 485–486, 5 illus.

The Compressibility Stall. C. N. H. Lock. Ideal streamlined fuselage should have a shock stall at 600 m.p.h. The whole of the propeller blade is subject to shock waves at 530 m.p.h., and the shock-wave effect must be considered on a motor nacelle at more than 400 m.p.h. Critical speed for a radial motor cowl is 450 m.p.h. and a cylinder would form a shock wave at 350 m.p.h. Large spinners and thin root sections are advised for the propeller. Brief abstract, Royal Aeronautical Society paper, and discussion. (Editorial Note: Preprint of this paper is obtainable from the Library.) Aeroplane, Aeronautical Engg. Supp. November 10, 1937, page 567. Flight, November 4, 1937, pages 450–452, 7 illus., 2 tables.

The Effect of Wing Loading on the Design of Modern Aircraft with Particular Regard to the Take-Off Problem. H. F. Vessey. Effect on performance and the problem of landing and take-off at present wing loading and at the higher wing loadings to be expected in the future. For modern clean high-performance aircraft, wing loading could be advantageously increased to loadings of 60 lb./sq. ft. or higher if landing and take-off restrictions could be eased. An upper wing loading of 30 lb./sq. ft. for landplanes, 35 lb./sq. ft. for flying boats, and 40 lb./sq. ft. for landplanes with front-wheel undercarriage with present type of flap is considered desirable for the normal medium-range aircraft of fairly low power loadings. Assisted take-off methods also discussed include accelerated take-off, use of an auxiliary aircraft (Mayo Scheme), and fueling in the air. Royal Aeronautical Soc. Preprint for Meeting, November 18, 1937, 26 pages, 9 illus., 2 tables, many equations.

The Gas Engine and After-Development of the Aeroplane. F. W. Lanchester. "A strong point against the low wing is that the body, being above the airfoil or monoplane structure is surrounded by air with a higher velocity of relative motion . . . . . it is time that the number of designs" of engines "should be drastically reduced, only those showing marked superiority being scheduled for further development." The four-engined monoplane for long-distance service is considered a permanent design. Conclusions on future designs, the remainder of the article being a historical review. Abstract, Institution Mechanical Engineers paper. Engineer, November 19, 1937, pages 556–557, 1 table.

Hafner and Cierva Gyroplanes. R. Hafner. Reply to J. A. J. Bennett's comparison of these designs. Control of the A.R.III and C.30, false hub and tilting hub, calculation of hand loads in the control column, loads and moments on the two types of hub, jump starts, over-revs., and tip-speed ratio. Flight, November 11, 1937, pages 471–472, 2 illus.

Harnessing an Old Enemy. By a special arrangement of outboard engines, not only is it possible to obtain the equivalent of maximum lift coefficients of more than three, but with wing loadings commonly used, remarkably low sinking speeds are attained, coupled with very steep approaches. These advantages are attained without sacrifice in maximum speed and with comparatively insignificant increase in weight and complication. Brief editorial commenting on experiments of Capt. G. Crouch. Flight, September 2, 1937, page 225.

Investigation of Airplane Vibration. The equations derived for three binary wing vibrations take into account the variability of the various elements, such as chord, mass per unit length, and rigidity along the wing. A general method is explained for calculating the corresponding critical velocity without forming an hypothesis on the variations of the deformations. Italian Air Ministry Report. L'Aerotecnica, August–September, 1937, pages 721–735, 3 illus., 30 equations.

More About This Tricycle Business. F. D. Bradbrooke. Eight main essentials which any new type of undercarriage must have to retain all important advantages of the old and to eliminate the present dangerous necessity for juggling with the stall in order to land classically. These points are discussed in regard to the tricycle landing gear and methods of landing airplanes. An editorial note expresses the opinion that "the tricycle undercart, in the way it has been used lately, is a most dangerous affair, except on very good aerodromes." Aeroplane, November 17, 1937, pages 597–598.

Calculation of Induced Drag for Small Aspect Ratio. F. Weinig. New equation for induced angle of incidence enables the calculation of the coefficient of induced drag. Evaluation of test results thus permits the determination of the residual profile drag and its analysis into surface and wing-tip drag. DVL report. Luftfahrtforschung, September 20, 1937, pages 434–437, 7 illus., 1 table, many equations.

Δt—As an Element in Design. T. C. Bennett. Temporary development of lift coefficients greater than those indicated under conditions of steady airflow, and the allowances to be made for them in design. Lift of airfoils started impulsively from rest at high incidence, loads developed due to presence of a gust normal to the flight path, gust gradients, and evidence that members behave differently under suddenly applied loads. Aviation, November, 1937, pages 32–33, 70, 72, 4 illus.

Longitudinal Dynamic Stability Calculated from Simple Wind Tunnel Tests. A. Klemin and J. G. Beerer, Jr. Methods employed are presented, and results are compared with those of full flight tests. Treatment is restricted to power-off condition, control stick neutral. Aero Digest, November, 1937, pages 53, 58, 2 illus., many equations.

Longitudinal Stability. H. B. Irving. Factors affecting stability with stick free, and existing data indicating the possibility of reducing the loss or even making some gain in stability with stick free. Stability with free and with balanced elevators; hinge moments on unbalanced elevators of 0.4 chord, on Martin M-1 elevators, and on Nieuport "London" ailerons; a form of balance embodying set-back hinge and outside horn; and effect of a geared balance tab on longitudinal stability with stick fixed and free. Flight, Aircraft Engr. Sup., October 28, 1937, pages 21–23, 4 illus.

New Ideas in Flaps. Marendaz flap is so placed that when it is fully depressed its leading edge is almost vertical to the rear spar, and in all extended attitudes there is a gap between its leading edge and the under side of the wing. Novel slotted flap on the Nardi F. N. 305 extending along the entire wing trailing edge; new Fairey flap (British patent No. 461,157) mounted about a transverse axis at or near its center of pressure; and slotted wing tips of the German Ago Kurier as well as its slotted flap completely retractable into the wing under surface at the trailing edge. Description of these flaps with drawings and photographs. Aeroplane, Aeronautical Engg. Supp., October 20, 1937, pages 481–482, 480, 13 illus.

Variable Span and Variable Wing Area. A. E. Parker. For aircraft of about 40,000 lb. gross weight, considerable increase of speed (24 m.p.h.) is gained by increasing wing loading from 20 lb./sq. ft. to 57 lb./sq. ft. (approx.) and saving in fuel weight is nearly 2200 lb. at the higher speed. Effect on speed of varying wing area (but keeping aspect ratio constant) of an airplane for constant all-up weight and a constant thrust horsepower is calculated. Continued. Flight, Aircraft Engr. Sup., October 28, 1937, pages 23–24, 2 illus., 6 tables.

Upper Tail Fin Produces Autorotation in the Flat Spin. Results obtained by P. de Haller, Zurich Aerodynamic Institute, opinions of von Kármán, and comments on the empennages of the Arado "Treff Ass" having very staggered controls and said to give good results for resistance to spins and autorotation. Les Ailes, October 7, 1937, page 9, 4 illus.

Misguided Ingenuity. Critism of the tricycle-landing-gear pusher-propeller type of airplane on the ground that "if and when the machine shoulders over, as we are convinced that tricycle undercarriages must, there is every prospect of the motor coming through onto the pilot's head and neck." Reference is also made to the Hammond which the K.L.M. intend that all their pilots shall learn to fly with the idea of getting them used to flying the Douglas D.C.4 when it arrives. Brief note. Aeroplane, November 17, 1937, page 583, 1 illus.

These Tricycles. A pilot's experiences with four different versions of airplanes fitted with tricycle landing gear, the Avion fitted with the Cowey third wheel, Scheidemusch pusher, a D.H. experiment, and a special Monospar. Special credit is given General Aircraft and the Douglas Company for their designs. Flight, November 11, 1937, pages 462–465, 10 illus.

Taxying Bumps. J. Corner. Criticism of a recent article by A. E. Parker, who discussed the loads thrown on airplane undercarriages by bumps in airport surfaces, assuming a rigid undercarriage. It is shown that when the deflection of the undercarriage is taken into account, the results are seriously modified. Flight, Aircraft Engr. Sup., November 18, 1937, page 34, 1 illus., many equations.

Time and Distance for Take-Off and Landing of Aircraft. General G. A. Crocco. Criteria for calculating the take-off and landing of airplanes and seaplanes are brought up to date from recent data on the variable-pitch propeller, flaps, aerodynamic braking, and models of floats. Long article L'Aerotecnica, August–September, 1937, pages 681–720, 35 illus.

Wasting Money. B. Shenstone. Criticism of the British Aeronautical Research Committee's Reports and Memoranda, especially of No. 1699 (287 pages) on three charges in regard to contents, cost, and production. "These appendices are quite incredible . . . . . Who in the World wants to know that a certain pilot aged 32 had ten children, which, although a notable performance in itself, can hardly affect the failure of an airplane?" Comparison with N.A.C.A. reports is also made. Aeroplane, Aeronautical Engg. Supp., November 17, 1937, page 589.

Stress Analysis and Structures

For "Cleaner" Skins. Colloquially known as "strip tease," the new Cellon process for covering rows of rivet heads, overlapping joints, and similar minor irregularities in metal sheet covering, is being tried out on the A. W. Whitley and Ensign, the Blackburn dive bomber, C. W. Cygnet, Miles

fighter-trainer, and Saro London. Aluminum foil, or other suitable strip, is coated with a thermoplastic adhesive which incorporates anticorrosive agents such as zinc chromate. Short description. Flight, September 2 1937, page 243, 4 illus.

Buckling of Bars with Non-Progressively Variable Moments of Inertia. B. Radomski. Buckling-failure conditions are derived for a bar with a moment of inertia variable non-progressively but constant over a certain length. Two cases are considered, one for a bar consisting of two lengths l_1 and l_2 with moments of inertia J_1 and J_2, and the other for a bar consisting of three lengths, l_1, l_2, and l_1, with J_1, J_2, and J_1 (symmetrical with respect to the center). Graphs plotted for different ratios of $J_1:J_2$ over $l_1:l_2$ show the mean moment of inertia J_m, with which the buckling strength of the bar with sudden variations of the moment of inertia can be represented in the Euler form. Report of the Focke-Wulf Flugzeugbau A. G. Luftfahrtforschung, September 20, 1937, pages 438–443, 4 illus., many equations.

Metal for the Light Airplane. J. P. Eames. Geodetic construction, application of thin magnesium sheet to aircraft manufacture, magnesium alloy structures, and beryllium alloys. Developments under investigation which may exert an enormous influence upon future progress of all-metal light airplane production. Concluded. Western Flying, November, 1937, pages 21–22.

Torsional Failure of Struts with Open Profile under Axial Compression within the Elastic Range. R. Kappus. Results derived by the energy method are presented and compared with those found by other writers. In the case of simple symmetrical open profiles, bending failures (that is, failure in which twisting does not enter) are possible only in direction of the axis of symmetry. For the direction at right angles to this axis, lateral failures (torsionless failures) occur only in the limited case of very great length or wall thickness. The theory of torsional failure developed constitutes a needed extension of Euler's theory of bending for open sections. DVL report. Luftfahrtforschung, September 20, 1937, pages 444–457, 11 illus., 169 equations.

Aircraft Maintenance

Air Terminals for Trans-Atlantic Services. H. S. Pack, Jr. Maintenance system developed by Pan American Airways for its large transoceanic flying boats is discussed, and the terminals and facilities at Port Washington, Long Island, and Baltimore are described. The precise technique developed for safe and efficient handling of the big flying boats on land or when not operating under their own power is outlined. Aero Digest, November, 1937, pages 46, 48, 50, 102, 4 illus.

Aircraft Take-Off (Assisted)

Catapult or—Air Tug? Assisted take-off for heavily loaded aircraft by means of catapult, starting rail, and composite aircraft are briefly reviewed in an editorial and towed starts for flying boats are suggested. Flight, November 4, 1937, page 436.

Composite Story. H. J. C. Harper. Past experiments made with composite aircraft. Bristol scout taking off from the Porte "Baby" flying boat, gliders released from the top wing of a D.H.9A and other aircraft, a B.E. 2c airplane attached to an S.S. type nonrigid airship and released in the air, and an airplane carried and released by large rigid airships. Flight, November 11, 1937, pages 468a–468c, 7 illus.

Aircraft

International Aero Exhibition in Milan. Comments on the Italian and German military and civil aircraft and engines exhibited. The Italian Air Ministry exhibit is briefly described and particulars of the Fiat A.80, R.C.20, and R.C.41, and the A.74, R.C.38, and R.C.I.38 aircraft engines are given in a table. Engineering, November 19, 1937, pages 579–580, 4 illus., 1 table.

New—and Not So New. German Hamburger Ha. 137B fighter-dive bomber. Italian Breda 88 multiseater fighter or bomber averaging 358.72 m.p.h. over 62.14 miles and 295.46 m.p.h. over 621.4 miles. Italian Romeo Ro. 51 single-seater fighter. Belgian Renard R. 36 having unusual wing formation and radiator for the Hispano Y engine. Small drawings only. Flight, November 18, 1937, page 489, 4 illus.

New Military Types. New Curtiss A-18 twin-motored attack monoplane "of a type that is very much 'as done'." Henschel general-purpose two-seater driven by one of the new inverted-twelve motors, and Henschel single-seat trainer with a motor which looks like a 240-hp. Argus inverted 8-cylinder vee. Photographs only. Aeroplane, August 25, 1937, page 232, 3 illus.

They Do it Differently. Features of military aircraft of other countries which seem unusual from the British point of view, including: the Curtiss Hawk 75 single-seater multigun fighter equipped with armament and tankage for medium-range bombing or attack work (photographs of under-wing surface showing bombs); Amiot and Fokker T.4 bombing, reconnaissance and patrol twin-float seaplanes; Curtiss YlaA-18 attack airplane for the U. S. Army Air Corps, and the Northrop attack equipped with containers for chemical dispensation; Japanese army cooperation machine hooking its message from an extraordinary height. Flight, November 4, 1937, pages 438–439, 6 illus.

Nebulous Fighters. Tandem-motor twin-fuselage midwing Bellancas, one hundred of which are to be built in Canada, and a design of A. H. Tiltman of Airspeed, Ltd. for a single-seat fighter (British patent No. 470,650) said to offer good view and low skin-friction drag. Motor of the latter appears to be a liquid-cooled four-bank X. Drawings only. Aeroplane, October 27, 1937, page 511, 4 illus.

France

A trap door in the fuselage of Morane Saulnier M.S.-405 has been arranged for launching new parachutes at high speeds. Also under consideration for these tests is a special cannon such as used for launching ropes to ships in distress. Brief reference and poor photograph of the airplane. Les Ailes October 7, 1937, page 8, 1 illus.

Amiot 150-Be seaplane for exploration and bombing (two Gnôme-Rhône 15-Krsd 740-hp. engines). Photographs only. Les Ailes, October 7, 1937, page 4, 2 illus.

Airplanes in Test. Hanriot H-220 three-place pursuit control and light bomber (two Gnôme-Rhône M-14 700-hp. engines, top speed 500–520 km./hr. at 4000 meters, two cannons). Potez 63 pursuit control and light bomber (Hispano-Suiza 14-AA 1100-hp. two-row radial engines). Marcel-Bloch 133 high-speed bomber (two Hispano-Suiza 14-AA engines). Marcel-Bloch 150 low-wing pursuit (Gnôme-Rhône 14-No. 1100-hp. engine, estimated speed 480 km./hr. at 4000 meters). Very brief references to these airplanes undergoing tests. Les Ailes, October 7, 1937, page 15.

The Bloch 220 at Croydon. New 18-seater transport fitted with two Gnôme-Rhône K.14 supercharged 870-hp. engines has achieved a top speed of 220 m.p.h. at a height of 7350 ft. Brief reference. Flight, October 21, 1937, page 412.

Photograph only. Les Ailes, October 7, 1937, page 8, 1 illus.

The Farman F-2231 Long-Distance Freight Transport. A. Frachet. High-wing braced transport designed for North Atlantic services has four Hispano-Suiza 12-Xirs 600-hp. engines arranged in tandem and covers at zero wind 8000 km. at an average cruising speed of 280/300 km./hr. The military version, a night bomber, will fly at high altitudes and should reach 420 km./hr. Top speed of the transport is 345 km./hr. Long description, characteristics and performances. Les Ailes, October 7, 1937, page 9, 4 illus., 2 tables.

The Four Winds. Indications are that France is starting a big drive for world's records. Curvale in the Bloch 160 (four Hispano X 690-hp.) covered 1000 km. with 5000-kg. load at 317 km./hr. average speed, and 307 km./hr. for 2000 km. Using the new tapered-wing Farman 2231 (same engines), Coupet averaged 262 km./hr. over 1000 km. with 10,000-kg. load. Farman is the prototype of a transatlantic series and of a high-speed heavy bomber. Flight, October 28, 1937, page 420. Les Ailes October 21, 1937, page 3. (Discussion of records.)

Miscounted Chickens. French Air Ministry has decided that the Latecoère flying boat, "Lieutenant de Vaisseau Paris" has not enough reserve range for the 2500 miles from Biscarosso to St. Pierre and Miquelon islands, Newfoundland. The boat has an all-up weight of 39 tons for long-range purposes and motors are six Hispano-Suiza V-12s of 890-hp. Cruising speed is said to be 142 m.p.h. Brief note. Aeroplane, October 20, 1937, page 487.

Achievements of the Farman 2231. Loaded at 22,500 kg. the Farman took off in 1300 meters in 51 seconds and covered the Istres-Chaumont circuit of 1000 km. in 3 hr., 48 min., 46 sec. Brief note. Les Ailes, October 21, 1937, page 3.

Airplanes in Test. First issue—Potez 63-1 light bomber and pursuit control (two Gnôme-Rhône 14-Mars engines of 1300-hp.), and the Marcel-Bloch 203 (two Clerget 500-hp. 14-cylinder double radial heavy-oil engine).

Second issue—Loire-Nieuport 161 single-seater pursuit (Hispano Suiza 12-Ycrs developing 860 hp. at 4000 meters, speed nearly 480 km./hr.). Hanriot H-220 (two Gnôme-Rhône M-14 1300-hp.). Brief references to tests of these military airplanes and to commercial and racing airplanes in test. Les Ailes, October 21, and November 4, 1937, pages 15, 15.

The Four Winds. Morane concern is erecting the first eleven of the MS 405 single-seater fighters (Hispano cannon engine) of the large batch ordered by the French Air Ministry. An improved fighter, the MS 420 is estimated to be capable of 320-odd m.p.h. Brief reference. Flight, November 4, 1937, page 444.

Farman 2230 being built for Air France Transatlantique will have a fuselage designed for flotation in case of a forced descent and a supercharged cabin, and will normally fly at heights between 20,000 and 26,000 ft. Brief reference. Flight, November 11, 1937, page 466.

Hanriot H230 Military Trainer. Bimotored two-place monoplane can also be used as a postal liaison airplane. Powered by two Salmson 6-cylinder inverted aircooled 270-hp. engines it has a top speed of 265 km./hr. at 500 meters and range of 950 km. Characteristics and performance. L'Aérophile, October, 1937, page 218, 2 illus., 2 tables.

Latécoère-521. "Lieutenant-de-Vaisseau-Paris" flying boat recently flew the 5780 km. from Port-Lyautey to Maceio in 34 hours 37 minutes. Account of flight and photographs. Les Ailes, November 4, 1937, pages 1, 2–4, 5 illus.

A Stratosphere Farman. Farman 2230 built for Air France Transatlantique is derived from the 2231, has a deeper fuselage with water-tight surfaces and is designed to fly at 6000 to 8000 meters. Due to an interior envelope of rubberized fabric the pressure maintained in the passenger cabin at high altitudes will be analogous to that at 3000 meters, arrangements being made to regenerate the oxygen and absorb carbonic acid. Pilots will use the usual inhalers. Brief note. Les Ailes, November 4, 1937, page 8.

Germany

Powered with two Mercedes inverted vee twelves the Dornier Do. 17 medium bomber of the German Air Force is reported to be faster than a Blenheim. A gun position is located behind the pilot's cockpit. Photograph only. Flight, November 4, 1937, page 454, 1 illus.

The Fastest Heinkel. Two cannons, two machine guns, and six 20-lb. bombs are carried on the Heinkel He.112 fighter. Fitted with a Junkers Jumo 210 Ea water-cooled engine (660 h. hp. at 12,800 ft.) the machine is claimed to have attained a maximum speed of 310 m.p.h. Short description and drawing cutaway to show location of armament and other equipment. Flight, October 28, 1937, page 426b, 1 illus.

Junkers Ju90. "Crosse Dessauer," new 40-passenger transport having 4000 hp. total power, and speed around 400 km./hr. Photographs only. Les Ailes, October 7, 1937, pages 1, 4, 3 illus.

An Atlantic Heinkel. Heinkel He. 116 transport is powered by four Hirth HM. 508B inverted vee-eight 240-hp. engines and has a maximum speed of 205 m.p.h., range of 2670 miles, and landing speed of 68 m.p.h. Brief note and characteristics. Flight, September 2, 1937, page 232, 1 illus.

Construction, characteristics, performance. L'Aérophile, October, 1937, pages 223–224, 1 illus., 2 tables.

A Competitor. Dornier Do. 19 heavy bomber (four 715-hp. Bramo 322 aircooled radials) ordered by the German Air Ministry is reported to be wanted no longer as the heavy bomber is out of favor. Fast medium types are said to be preferred. Photographs only. Aeroplane, August 25, 1937, page 231, 2 illus.

Diesel-Powered Bombers. Junkers Ju. 86 bombers of the German Air Force are similar to the civil 86 and are fitted with a pair of Junkers Jumo 205 Diesel engines (510/600 hp.). A peculiar retractable dustbin turret is located below the fuselage. Photograph only. Flight, November 11, 1937, page 466, 1 illus.

The Four-Engined Junkers Ju-90 Transport. Powered with four Mercedes Benz DB 600 engines the 40-passenger transport has a maximum speed of 380 km./hr. and range of 1400 km. With four Junkers Jumo 211 1100-hp. engines, it has a maximum speed of 410 km./hr. and range of 3000 meters. Long description, characteristics, and performance. L'Aérophile, October, 1937, pages 221–222, 5 illus., 2 tables.

The Land-Speed Record. New World's Speed Record for land planes was established in Germany on November 11 when Dr. Wurster flew a

Messerschmitt Bf 109 single-seat fighter (Mercedes-Benz DB 600 engine) at a speed of 610.21 km./hr. (379 m.p.h.). Standard editions of the Bf 109 fighter, going into service in the German Air Force in large numbers, are reputed to have a top speed of 335 m.p.h. presumably at 13,000 ft. and to land at 56 m.p.h. Brief note. Aeroplane, November, 17, 1937, page 581.

Slotted and Flapped. New Messerschmidt B.F.W. Bf 109 single-seat fighters of the Luftwaffe may be powered with either a 900-hp. Mercedes Benz or 650-hp. Junkers, both inverted vee twelves arranged to take a cannon. Photographs only. Aeroplane, August 25, 1937, page 215, 2 illus.

The Four Winds. German Arado company has built an outstandingly versatile twin-float seaplane described as a semi-cantilever biplane. It is stressed for catapulting, has folding wings, carries bombs, torpedo or smoke-screen apparatus, and is capable of 196 m.p.h. presumably when carrying reconnaissance load. Brief reference. Flight, November 4, 1937, page 444.

Gotha Go-146 High-Speed Mail Airplane. A. Frachet. Light airplane of mixed construction (two Hirth 200-hp. engines) transports four persons over 950 km. at a cruising speed of 295 km./hr. With one engine off it maintains a height of 1800 meters. Long description. Les Ailes, October 21, 1937, page 9, 3 illus., 2 tables.

Heinkel He. 112 Single-Seater Pursuit. Low-wing monoplane powered with a Junkers Jumo 210 Ea 12-cylinder inline water-cooled engine developing 685 hp. at 3600 meters. A retractable radiator is situated below the engine. The pursuit is equipped with two machine guns in the fuselage and two cannons in the wing. Top speed is 485 km./hr. at 3600 meters. Armament, construction, characteristics, and performance. L'Aérophile, October, 1937, page 218, 1 illus., 2 tables.

The He. 112 has been demonstrated before Swiss authorities. An inverted-vee Mercedes Benz has been installed on the He. 70 single-engined transport with marked gain in performance. Brief reference. Flight, November 4, 1937, page 444.

GREAT BRITAIN

A Modern Heavy Bomber. Both the Armstrong-Whitworth Whitley II and III have Tiger VIII engines with two-speed supercharger (845 hp. at 6250 ft., 780 hp. at 14,250 ft.). Reference to the Nash and Thompson power-operated gun turrets and new type of bomb rack of the Whitley III; gun turrets fitted in the extreme nose and tail; a retractable cupola located in the fuselage bottom; front cockpit's hinged window in the nose below the turret and a course-setting bomb sight; and emergency exits. Ranges between 1250 and 1600 miles; speed 200 m.p.h. with a disposable load of 7385 lb. Very long description covers: Comparison with the Ensign; details regarding materials and design of structural members, illustrated by many drawings; bomb stowage; powerplant installation; performance data with two Tiger IXs; air impressions; and list of firms whose products are used in the Whitley. Flight, October 21, 1937, pages 396–402, 395, 23 illus.

On Rotary Aspirations. R. Hafner. Hafner A.R.3 gyroplane can land quite vertically with no forward run at all. It is an experimental machine powered with an 84-hp. Pobjoy Niagara III engine, carries one passenger and has a maximum speed of 115 m.p.h. Hub of the rotor turns about a rigid axle through which all flying loads are carried direct to the fuselage. Incidence is varied by a separate complete control linkage to the control column. Long description of design and development. Royal Aeronautical Society paper, and discussion. Aeroplane, Aeronautical Engg. Supp. October 20, 1937, pages 478–480, 5 illus. Flight, October 21, 1937, pages 407–408, 1 illus.

The Trainer Hind. Hind (T) for "ab initio" training in the British Services will be developed from the standard Hind light-bomber design by fitting complete dual control and a special rear cockpit with parachute seat. With Kestrel V engine maximum speed at 14,000 ft. should be around 200 m.p.h. Brief note. Flight, October 21, 1937, page 405.

Gyroplane and Autogiro. J. A. J. Bennett. Comments on Herr Hafner's paper. AR III gyroplane is compared with the Autogiro in regard to: false-hub type of control; longitudinal flapping; torsionally-flexible tension member used for carrying centrifugal force of the blades; restoring moment due to torsional elasticity which tends to stabilize the blades at predetermined incidence; direct take-off; behavior of the ideal rotor; and interlapping of flapping hinges to control undesirable moments. Flight, Aircraft Engr. Supp. October 28, 1937, pages 25–26, 1 illus.

Swan and Cygnet. C. W. Swan light transport (six passengers) and the production-type Cygnet two-seater are described in detail. Powered with two Wasp S.B. or Whirlwind 975-E-3 the Swan has a top speed of 250 m.p.h. and cruising range of 700 miles. It may also be powered with two Gipsy Six Series I or Series II engines. Long description. Flight, October 28, 1937, pages 421–423, 9 illus., 1 table.
Shorter description. Aeroplane, October 27, 1937, page 518, 2 illus.

Boots. Airspeed Queen Wasp radio-controlled flying target on floats has been built for the Navy. It is faster than the Queen Bee for it has more power (355-hp. Siddeley Cheetah IX radial). Photographs only. Flight, November 4 and 11, 1937, pages 437 and 486g, 4 illus. Aeroplane, November 10, 1937, page 553, 1 illus.

A Napier-Engined Bomber. Improved version of the Handley-Page Hampden medium bomber will mount a pair of Napier E. 108 engines of 16.8 liters capacity. This engine is provided with a D.H. constant-speed propeller and has front and rear ends of entirely new design and increased fin area. A Fairey Seafox two-seater light reconnaissance seaplane is fitted with a Napier H. It is a lightly loaded biplane with very comprehensive slinging gear, sprung floats, and provision for catapult launching. With a moderately supercharged Napier Rapier VI the seaplane has a top speed of 123.5 m.p.h. Brief reference. Flight, November 4, 1937, page 454.

Showing the World. The Wellesley bomber is suggested for beating the World's long-range record. Comments are made on the fact that, in this plane, the pilot cannot move from his seat while the machine is in the air, which would indicate that the machine is to be used by the Royal Air Force as a short-range bomber carrying a very large load. Editorial. Aeroplane, August 25, 1937, pages 213–214.

HOLLAND

Fokker T5 Bimotored Bomber. Medium-wing bomber (two Bristol Pegasus XX 925-hp. engines) has a top speed of 390 km./hr. and range of 1450 km. A cannon is located in a turret in the nose with bomb sight and a second cannon can be installed. Armament, construction, characteristics, and performance. Brief. L'Aérophile, October, 1937, page 219, 1 illus., 2 tables.

LATVIA

A Visitor from Latvia. Latvian J-12 touring monoplane powered with a 90-hp. Cirrus Minor and having a top speed of 149 m.p.h. Brief description and performance. Aeroplane, September 1, 1937, page 267, 2 illus.

U. S. A.

New design principles have been incorporated by Dr. Max M. Munk into a large-aspect-ratio flying-wing type of airplane which has been built at the Kellett factory in Philadelphia. Brief reference. Aero Digest, November, 1937, page 92.

The Aeronca Models K and KC for 1938. Model K two-place high-wing cabin monoplane is offered in a choice of three powerplants, the Aeronca E-113C, and the Continental A-40-4 or A-40-5, and has a top speed of 88–93 m.p.h. Long description of both models. Aero Digest, November, 1937, pages 64–65, 4 illus., 2 tables.
Shorter description. Aviation, November, 1937, page 40, 2 illus., 1 table.

Gwinn Introduces Aircar. Small rudderless biplane having tricycle landing gear and powered by a Pobjoy Niagara II or V engine. Maximum speed with latter 137 m.p.h. Short description. Western Flying, November, 1937, page 31, 1 illus., 1 table.

Improvements in the New Stearman-Hammond Yl-S. Airplane having tricycle landing gear and powered by a 150-hp. Menasco C4S engine giving a maximum speed of 125 m.p.h. Detailed description of new model. Aero Digest, November, 1937, page 62, 3 illus., 1 table.

More Boeing Bombers for the Air Corps. Boeing B-17B bombers "generally regarded as the world's fastest bombers." A few details. U. S. Air Services, November, 1937, page 35.

Few details of the Boeing XB-15. Western Flying, November, 1937, page 27, 1 illus.

Planes for High Altitude Service. First of a series of none high-altitude type Douglas DC-3s delivered to Pan American Airways. Few details and routes they will fly. Western Flying, November, 1937, page 34.

Rearwin Model 6000 Speedster. Model 6000M is powered by a 125-hp. Menasco C-4 and has a top speed of 150 m.p.h. while the 6000MS, powered by a 150-hp. supercharged Menasco C4S, has a top speed of 163 m.p.h. Detailed description, characteristic, performance. Aero Digest, November, 1937, page 44, 4 illus.

Seversky in Foreign Competition. Convoy Fighter released for export, may be equipped either as an advanced training plane (550-hp. Wasp engine) or as a pursuit (1000-hp. Cyclone). Short description and specifications. Western Flying, November, 1937, page 30, 1 illus., 1 table.

Spartan All-Metal Executive. Carrying a useful load of 1413 lb. and powered by a P & W 450-hp. Wasp Jr., this five-place transport has a cruising speed of 205 m.p.h. at altitude and a cruising range of 950 miles. Long description, characteristics, performance, equipment. Aviation, November, 1937, pages 34–35, 10 illus.

A Study in Scaffoldings. Photographs illustrate the 65,000-lb. flying boat built by Glenn L. Martin Company for the Soviet Government, and the LZ-130 airship, both in the process of construction. Aviation, November, 1937, page 59, 2 illus.

Boeing B-17 bomber of the U. S. Army Air Corps carries a useful load of 3000 to 3500 kg. at a maximum speed of 400 km./hr. with a range of 4000 km. and a ceiling of 7000 meters. The XB-15 prototype is equipped with Twin Wasp 1000-hp. engines but will be powered with 1500–2000-hp. engines. Photograph of the XB-15. Les Ailes, November 5, 1937, page 8, 1 illus.

Three views of the Boeing XB-15 bomber and one of the Bell. Aeroplane, November 10, 1937, pages 515, 553, 4 illus.

A Formidable Multi-place Fighter. A. Klemin's comments on the Army Air Corps XFM-1 fighter. Brief. Scientific Am. November, 1937, page 307, 1 illus.

The Four Winds. The thirteen twin-engined attack monoplanes being built for Service tests with the U. S. Army Air Corps have two G-type Cyclone engines, four guns in the nose, racks for fragmentation bombs in wings and fuselage, and a gun over the rear cockpit. Brief reference. Flight, September 2, 1937, page 231.

Patrol Bomber. U. S. Navy Sikorsky XPBS flying boat is said to resemble the Short Empire type. Armament includes bow, midships and tail gun turrets, the tail position being of exceptionally neat design. Brief description. Flight, September 2, 1937, page 234c, 3 illus.

Rational Unorthodoxy. Comments on the Stearman-Hammond all-metal pusher with tricycle landing gear. This machine has been bought by K.L.M. to prepare its pilots for landing the new Douglas D.C.4s. Long article. Flight, November 18, 1937, pages 482–484, 8 illus., 1 table.

Service Load. "Although the armament (two or four machine guns) of the Curtiss P-36 single-seater pursuit . . . . may seem comparatively small, the machine carries very comprehensive equipment . . . . In the prototype at least, the engine has a striking cowling, the orifice of which is of rounded diamond shape." Very brief comments. Flight, November 18, 1937, page 490.

U. S. S. R.

260 M.P.H. Soviet "G.P." Bogdanov has produced a two-seater general-purpose machine having an 840-hp. M-34 engine, all-up weight of 5280 lb., and top speed of 260 m.p.h. Brief reference. Flight, November 4, 1937, page 454.

A Russian tailless airplane designed by Tcheranovski and equipped with two 100-hp. engines, reached the speed of 200 km./hr. with five persons on board. Brief reference. Les Ailes, October 7, 1937, page 8.

Alighting Gear

Tail Skid Replacement. Series of flexible tail wheels developed by H. Martin can be installed on Cub, Rearwin, Taylorcraft, Porterfield, and Aeronca aircraft to replace standard tail skids. Short description. Aero Digest, November, 1937, page 72, 3 illus.

Air Transportation

Air Transport in China. Development of airlines and their present operation which is said to continue in spite of the Japanese invasion. Aeroplane, October 27, 1937, page 512.

Airplanes at Work in the Mining and Petroleum Industries. W. E. D Stokes, Jr. Equipment of the various companies, operating costs per month and notes on aerial surveys for geological purposes. Aero Digest, November 1937, pages 24–29, 18 illus., 7 tables.

Aviation in the Netherlands. P. Masefield. Account of a flight from Croydon to Amsterdam in a Douglas D.C.3, and shops and overhaul methods of K.L.M. Leading-edge deicing overshoes were so badly perforated by discharges of static electricity through the leading edges, when flying through cloud, that they were liable to come off in the air and had to be removed. Aeroplane, September 1, 1937, pages 256–259, 5 illus.

Air Transportation. B. Johnson. Progress during the period 1927–1937 referring to cut of 50 per cent in transcontinental flying time, increased comfort and safety, radio improvements, and other developments. Scientific Am., December, 1937, pages 327–330, 10 illus.

Do Air Transports Offer as Much Security as Surface Transports? E. D. Weiss. Aviation accidents in the United States, Great Britain, and Germany are analyzed according to whether the cause was personnel, equipment external circumstances. Security offered by other modes of transport are compared with that offered by air transport. L'Aéronautique, October, 1937, pages 239–246, 2 illus., 10 tables.

Historical Review of Practical Tests of Commercial Aviation over the North Atlantic. Table of events and distances for the period 1928–1937. L'Aérophile, October, 1937, pages 226–227, 1 table.

An Imperial Year. J. G. Beharrel. Past and future of Imperial Airways as visualized in the chairman's address. Flight, November 18, 1937, pages 493–494, 1 illus.

Balloons

Eleven Free Balloons at the Race at Bitterfeld, Germany. Reference to the balloon "Elektronmetall" piloted by Dr. Rohbein is made in a brief note. Les Ailes, October 21, 1937, page 5.

Something New and Strange. One of the kite balloons, presumably from Cardington's Balloon Barrage, which have lately arrived in France without crew or escort. Photograph only. Aeroplane, November 17, 1937, page 580, 1 illus.

Austria. Hot-air balloon reached an altitude of 9500 meters in an ascent lasting nearly 2½ hours. Brief reference. Les Ailes, October 7, 1937, page 6.

High-Altitude Flight

The Optimum Altitude Is 20,000 Feet, Say the Engineers. But Why Not Go Higher? Conclusions reached by Pan American and TWA engineers that 20,000 ft. is the optimum altitude for operation of commercial aircraft, and references to the Boeing 307-S for Pan American. Western Flying, November, 1937, pages 15, 25.

Propellers

Airscrews and Air Fires. Fires breaking out in cowlings as a result of oil leaking from hydraulic systems of variable-pitch propellers. In a recent issue this was announced as a cause of accidents to airliners in America. Bureau of Air Commerce and other letters are offered to contradict this statement. Aeroplane, October 27, 1937, page 500.

Gyroscopic Effect on Propeller Shafts. K. H. Falk. Gyroscopic stresses in propeller shafts are often serious, depending on type of airplane and maneuverability encountered. Polar moment of inertia of a propeller and angular velocity of the airplane are main factors of the gyroscopic forces. Calculations given show that these forces cannot be neglected in shaft design, and examples indicate the general high stresses from this one acting force alone. Curve illustrates moment of inertia of two types of aluminum alloy propellers. Aero Digest, November, 1937, pages 56, 58, 5illus., many equations.

New Ideas in Airscrew Design. "Practical Airscrew Performance," F. W. Caldwell, F. M. Thomas, and T. B. Rhines. Abstract of Royal Aeronautical Society paper and the discussion following. Practice and theory as alternative bases for propeller design are considered by A. H. R. Fedden, D. R. Pye, Captain, F. S. Barnwell (Bristol Aeroplane Company), and other representatives of the British aircraft industry. (See TECHNICAL DATA DIGEST, November 15, for abstract of preprint.) Aeroplane, Aeronautical Engg. Supp., October 27, 1937, pages 508–511.

Rotol Airscrews. Three-bladed Rotol propeller having blades forged of magnesium alloy and screwed into a steel socket. Design and production methods. Aeroplane, November 10, 1937, pages 568–569, 5 illus.

A Single-Blade Variable-Pitch Propeller. A. Klemin. Sensenich-Everts propeller is said to have given pilots much satisfaction. Short description. Scientific Am., November, 1937, page 309, 2 illus.

V.P.—V.G. After 593 hours 55 minutes of flying duty a DeHavilland three-bladed variable-pitch propeller was removed for complete overhaul from its Bristol Pegasus engine on the transatlantic boat Cambria. Only components necessary to replace were the front cone packing washer and two cup leathers on the piston. Propeller was in perfect balance. Brief note. Flight, September 2, 1937, page 242.

Aircraft Instruments and Navigation

Complementary Development. By means of an infrared emission detector the two instruments referred to register the presence and approximate position of different objects. The development appears to have definite possibilities for use in the guidance of aircraft in conditions of bad visibility, or, in war, for the detection of enemy aircraft. Brief editorial referring to devices being developed along similar lines by F. D. Aldridge and a retired American naval commander. Flight, September 2, 1937, page 242.

Automatic Control and the Chemical Industries. L. de Florez. Aircraft control apparatus developed by the author is controlled chiefly by the rate of turn and assumes the function of an automatic pilot. Pressure differential in turn serves to actuate a vacuum-operated piston connected to the rudder which opposes the turn. Brief explanation of this device is given in an article on advantages of automatic control in chemical plants. Industrial and Engineering Chemistry, Ind. Ed., November, 1937, pages 1210–1213, 3 illus.

Fuel-Gauge Simplicity. Latest K.D.G. Nutsford VIII gauge. Metal pressure box is externally attached to fuel-tank base. Difference in pressure between inside and outside of indicator capsule gives head of fuel in tank irrespective of airspeed or altitude pressure at the vents. Brief note. Flight, October 21, 1937, page 404.

Tachometer. Kollsman Types 278-01, 301R-01 and 277-01 electric tachometer sensitive through a range of 3500 r.p.m. Short description. Aviation, November, 1937, page 46, 1 illus.

Weems Watch. Second-setting instrument designed by Commander P. V. H. Weems in collaboration with Longines-Wittnauer Company. Brief note. Aviation, November, 1937, page 47, 1 illus.

NAVIGATION

The Astronomical Position. A. Bastien. Calculation of an astronomical position which permits the two elements, height and azimuth, to be determined almost instantaneously. L'Aérophile, October, 1937, pages 235–236, 3 illus.

Airports

Atlantic Echoes. Lighting scheme and other features of the new Newfoundland airport at Gander Lake which is being developed for North Atlantic air services. Flight, November 11, 1937, page 476.

More about the Singapore Airport. "Singapore's Airport is not only the finest airport in the British Empire, it is probably the finest in the World." Main features of the airport, its development, and radio control. Aeroplane, November 17, 1937, pages 589–590, 2 illus.

Airport Equipment

Clearing the Deck. C. M. Newton. Cutlift combine installed at Sywell airport cuts grass and automatically loads it into a trailer. Short cuttings are taken immediately to the airport dryer and converted at the rate of 3½ cwt./hr. into better fodder than hay. Aeroplane, October 20, 1937, page 471, 1 illus.

Mobile Light House. Mobile airport lighting equipment ordered by the British Air Ministry for all fighter and bomber squadrons. On a Brockhouse trailer is mounted a Coventry Climax engine which drives an E.C.C. generator supplying power to the 5-kw. dioptric floodlight. Small 12-volt generator is used to charge Nife accumulators for interior and exterior lighting. Detailed description of trailer and floodlight. Flight, October 21, 1937, page 404d, 3 illus.

Armament

Czech Armament. Armament of newest prototypes. Letov two-seater fighter with two guns in the wing and another pair over the rear cockpit; three-seater twin-engined reconnaissance type having four wing guns and another firing below the tail; and Avia 35 fighter resembling a Hurricane but having a Hispano-Suiza V cannon engine and two synchronized machine guns. Brief reference. Flight, October 28, 1937, page 432.

Artillery Mounted in Aircraft. Photographs illustrate: effects of an Oerlikon shellburst on fabric-covered and metal-covered wings; comparison of range of aircraft machine guns and cannon; mounting of the Hispano-Suiza cannon; design of modern motors to suit aircraft cannon; pursuit plane having aircooled radial engines and armed with cannon and machine guns mounted in wing; comparison of cannon shell and machine-gun bullet; some methods of mounting armament of modern fighting aircraft (Dewoitine D-510, proposed Burnelli, Potoz, Fokker G-1, Gloucester Gladiator, Loire fighter); special type of turrets mechanically rotated and accommodating cannon; and the Oerlikon cannon. Army Ordnance, November–December, 1937, pages 152–153, 20 illus.

Ice Elimination Equipment

Deicing by Bradshaw. Deicing system to be tested by the British Air Ministry utilizes a fine-weave metallic matting which, when deformed by suitable mechanical means, in turn deforms a large number of suitably shaped minor surfaces. The matting is woven from thin metal strips of flattened oval section and is placed over leading edges of the wing. Modification is being developed for propellers. Short description. Flight, November 4, 1937, page 456, 2 illus.

Ice Prevention. Killfrost (developed by J. Halbert and used on all Imperial Airways aircraft) is smeared on leading edges and control joints of airplanes in order to prevent ice formation. Water cannot turn into ice in its presence whatever the temperature. Brief reference. A second note reviews a book issued by the Meteorological Office by G. C. Simpson and entitled "Ice Accretion on Aircraft." Flight, November 11, 1937, page 477.

Icing of Ailerons. Temporary jamming of the lateral control occurred in an experimental flight to test deicing equipment when the aircraft entered a region in which temperature was about 0°C. after having flown in very severe icing conditions. It was thought that loose ice found its way into the gap in front of the balance portion of the aileron. Instructions for handling the aircraft are given. The same information is contained in a second brief note quoting a recent British Air Ministry order. Flight, September 2, 1937, pages 238, 242.

Lighting Equipment

Lighting Research at Wembley. Research laboratories of the (British) General Electric Company, their equipment, and work being carried on. Reference is made to an experimental smoke wind indicator for airports. Engineering, November 5, 1937, pages 523–524, 3 illus.

New Route Beacon. British G.E.C. experimental air route beacon. Pilot does not see the actual light source but two reflections of it. Brief note. Flight, November 11, 1937, page 478, 1 illus.

Parachutes

The Four Winds. Latest parachuting record is claimed by a Russian who jumped from an airplane at 36,000 ft. Brief reference. Flight, September 2, 1937, page 231.

Parachute Jump Across the Channel. E. Denois. Plans for a parachute jump starting over England and landing on the coast of France, and a few details of the oxygen inhaler, and special parachute designed to carry a training nacelle of 70 kilos containing two passengers. L'Aérophile, October, 1937, page 228, 2 illus.

Tail Chutes. British Air Ministry now demands that all aerobatic type of aircraft to be submitted to spinning trials be equipped with a small parachute fitted to the tail. Brief reference. Flight, November 11, 1937, page 470.

Materials

Sewn Air. Tropal Java Kapok for airplane soundproofing and flying suits is a very fine-fiber material in which each minute cylindrical fiber tube is filled with air. Material is said to be lighter than cotton and warmer than fur, and to absorb no moisture. Brief reference. Aeroplane, September 1, 1937, page 268.

A New Alloy. Hiduminium R.R. 77, new aluminum-base alloy, developed by High Duty Alloys, Ltd., for use in highly stressed structural parts of an airplane, has a specific gravity of 2.8. It is said to be unsurpassed on the basis of yield-strength-to-weight by any other material so far available, and to possess excellent qualities of ductility, electrical and thermal conductivity, and resistance to corrosion and fatigue. Physical and mechanical properties given. Aeroplane, November 10, 1937, page 576, 2 tables. Flight, Aircraft Engr. Sup., November 18, 1937, page 33, 2 tables. Metal Industry, November 12, 1937, page 478, 2 tables.

Sealing Sheet Metal Joints and Seams. P. A. Beck. Sealing material developed is an impregnated cotton fabric (neoprene pressed into cotton fibers) faced on either side with a neoprene compound. On each surface is added a layer of dry cement incorporated with a corrosion inhibitor. Development of this material, tests made by Sikorsky and Lockheed companies, characteristics of the material, and technique in applying it. Aero Digest, November, 1937, pages 38, 40, 102, 3 illus.

Application of Aircraft Finishes. G. H. Robertson. Practical suggestions for producing workmanlike finishes on aircraft, covering: doping, pinholing and wrinkling, tautening of fabric, thinning procedure for dope, metal finishing, and reduction of fire hazard. Aero Digest, November, 1937, pages, 32, 65, 1 illus.

Substances Having Synthetic Resin Base and Aeronautical Construction. R. Hamard. Mechanical properties (density and resistance) of these materials compared with wood and metals normally used. Parts of N. A. de Bruynes' recent paper before the Royal Aeronautical Society, and references to results of recent original French tests for introducing synthetic resins in fiber structure of wood. L'Aéronautique, October, 1937, pages 231–235, 1 table.

Engine Design and Research

Mercedes-Benz Antichamber Diesel Engine. Fraulein de Leires. Reported investigation of this engine is said to be an excellent contribution to information on flow processes in antichamber fuel-injection engines. As well as drawings and data for the antichamber curves are given for the antichamber and cylinder: maximum pressure at various antichamber openings and r.p.m.; pressures when engine is driven from the outside; maximum flow velocity in antichamber openings for driven engines and various r.p.m.; exponent of the compression polytrope increasing with r.p.m. but remaining constant in case of open and closed antichamber openings (warm engines); pressure distribution dependent upon injection time; largest flow velocity in the antichamber opening around upper dead center with engine ignition; performance for various r.p.m. dependent on injection fuel quantity; and pressure distribution depending on injection timing. Antichamber and cylinder pressure indicator cards also shown. A.T.Z., October 25, 1937, pages 508–511, 14 illus., 7 tables.

The New Development of Side-Valve Carburetor Engines. In spite of various tests (Argus As 16, Szekely, MacClatchie, Hudson, and Continental engine tests) side-valve aircraft engines have not exceeded the modest attempts of development of the GAl-V-4 aircraft engine. Applications of side-valve design to sport engines, Diesels, and wood-burning gas engines as well as to airplane engines are discussed. New attempts to increase resistance to knock, measures for improving filling, cylinder-head design and materials, and cylinder-block design are considered. A.T.Z., October 10, 1937, pages 476–483, 25 illus.

The Ragoucy Distribution of Fuel by Small Pneumatic Auxiliary Piston. C. Ragoucy. Two-stroke engine of high efficiency operates under the double effect of vacuum due to the exhaust and pressure due to introduction of fresh mixture, and for each speed and r.p.m. permits the intake port to be opened at precisely the right moment. Small auxiliary piston entirely free is located beside the principal piston and its vertical displacement is only to uncover the intake port, operating somewhat as a throttle valve. Long description. Les Ailes, October 7, 1937, page 7, 3 illus.

Cooling Problems. R. M. Helsden. Calculations intended to disprove the suggestion that it should be possible to recover some of the heat energy now carried away by airflow over the cylinders of aircooled engines or through the radiator of a water-cooled one, and the possibility of a jet-propulsion heat engine. Correspondence. Flight, October 28, 1937, page 433, 1 illus., many equations.

Crank Spacing for Two-Stroke Multi-Cylinder Engines. Crank spacings formerly ruled out by considerations of torsional vibration are now permissible. Table shows mass-balance characteristics of six-cylinder and eight-cylinder double-acting two-stroke engine used in many ships. In what appears the most advantageous arrangement, six throws are equally spaced at 60 degrees. V.D.I., October 16, 1937, pages 1219–1222, 5 illus., 3 tables.

Brief abstract. Automotive Industries, November 6, 1937, page 666.

Fuel Systems for Two Fuels. B. Demtchenko. Problems involved in the design of apparatus to furnish a special fuel of high antidetonating value for take-off and flight at full power. Principal requirements of automatic separation of the fuels and safety attainable by such an installation are pointed out. The series of arrangements described for main tanks and intermediate tanks containing the special fuel have been tested out in most cases in the laboratory of the Establissments A.M. Solutions to the problem which use a pump for supplying the special fuel are considered to offer much better possibilities than purely hydraulic solutions. L'Aéronautique, L'Aérotechnique Supp., October, 1937, pages 113–119, 7 illus., 16 equations.

Technical Notes. The Army Air Corps will join enginering specialists in solving problems of heavy-oil engines in order to fulfill the desire of the American Government for the production of Diesel aircraft engines of 2000 hp. Preliminary research has been carried out by the N.A.C.A. Brief note. Les Ailes, November 4, 1937, page 9.

Using Exhaust Gases to Aid Propulsion. Form of jet propulsion whereby air used to cool the engine and heat energy of the exhaust gases are both utilized to increase propulsive effort in the airplane. Brief note on invention of two officers of the Royal Aircraft Establishment at Farnborough. Scientific Am., December, 1937, page 372.

Engines

The 150 Hp. Cirrus "Major 150" Engine. New four-cylinder inverted inline aircooled British engine rated at 138 hp. at 2200 r.p.m. and 150 hp. at 2400 r.p.m. Short description. Aero Digest, November, 1937, page 80, 2 illus.

Model S-5-125 Security Engine. Five-cylinder radial aircooled aircraft engine rated at 125 hp. at 1950 r.p.m. Compression ratio is 5.1:1 and weight 325 lb. Long description. Aero Digest, November, 1937, page 54, 3 illus. Aviation, November, 1937, page 42, 1 illus., 1 table. Western Flying, November, 1937, page 31, 2 illus.

Parts and Accessories

Automatic Power Control. J. H. Millar. Primarily designed to meet British military requirements, the Hobson Master Control Scheme not only relieves the pilot of all responsibility for his engine but reduces in number and simplifies cockpit controls. A supercharged high-duty engine driving a constant-speed propeller may be completely controlled by one lever only. The three ranges of supercharge pressure are co-related automatically with three appropriate mixture strengths. The Hobson-Swann ice eliminator is combined with the Hobson electrical ice-warning unit. Long description. Aviation, November, 1937, pages 38–39, 75, 5 illus.

Resilient Connection on Aircraft Engines. Magneto drive shaft is connected to the magneto by an elastic resilient molded neoprene disk. Few details of connection used on Pratt & Whitney engines. Aero Digest, November, 1937, page 74, 1 illus.

Air-Cooled. New Isotta-Fraschini Asso A.120 I.R.C.C. 40 (Delta) 12-cylinder inverted aircooled aircraft engine designed to give 770 hp. for take-off and weighting 1190 lb. Two views, one calling attention to arrangement of the hollow propeller shaft to take a cannon. Aeroplane, November 10, 1937, page 569, 2 illus.

The Bristol Hercules Aero Engine. Reasons influencing the Bristol company's decision to use sleeve valves for future aircraft engines, and a description of the 14-cylinder two-row radial sleeve-valve Hercules engine which develops 1325 to 1375 b. hp. (maximum power for 5 minutes) at 2750 r.p.m. at 4000 ft. Engineering, November 12, 1937, page 553, 1 illus.

Earl's Court Show Review. Trend in design of automobiles and engines indicated at the British automobile show, and critical survey of exhibits. Special issue. Automobile Engineer, November 4, 1937. Entire issue, many illus.

A Good Start. "Although the Curtiss Conqueror is now obsolete, the U. S. Army Air Corps will not release any information about these turbo-superchargers, and we notice that the twin motors of the new Bell pusher have the same gear on their Allison motors." Reference made in connection with comments on the advantages of the unusual placing of the supercharger for the Mercedes-Benz DB-600. Performance of the DB-600 A/B and C/D, and a few details also given. Aeroplane, November 17, 1937, page 596, 1 illus.

An Improved Twin. Luton-Anzani 35-hp. inverted-twin engine. Photograph and reference to modifications. Flight, November 11, 1937, page 470, 1 illus.

International Aero Exhibition in Milan. Particulars of the Fiat A. 80 R.C. 20 (1100 hp.), R.C. 41 (1000 hp.), and A.74 R.C.38 and R.C.I.38 (840 hp.) aircraft engines are given in a table and reference made to a new Fiat A.82 R.C. aircooled radial capable of developing 1500 hp. and having an increase of 75 per cent in cooling surface over the 1000-hp. model. Aircraft exhibited are also described. Engineering, November 19, 1937, pages 579–580, 4 illus, 1 table.

The Inverted Mercedes. Daimler-Benz Mercedes BD-600 inverted vee-twelve liquid-cooled aircraft engine has been applied to the successful Dornier Do. 17 and Messerschmitt Me. 109 monoplanes. The DB-600 uses gasoline and there are rumors of a direct-injection model Ground-boosted engine is rated at 800 hp. at 2000 r.p.m., and the C-D engine at 800 hp. at 2200 r.p.m. at 13,000 ft. Short description. Flight, September 2, 1937, page 232, 1 illus.

The Pegasus XVIII. Two-speed supercharger and definite advances in aircooled radial poppet-valve practice are said to be interesting developments in the Bristol Pegasus XVIII 9-cylinder radial aircraft engine. Fin area is 2910 sq. in. per cylinder. In "M" gear take-off power is 980 hp. at 2475 r.p.m. and maximum power (5 minutes) 940 hp. at 2600 r.p.m. at 6500 ft. Very long detailed description but only a reference to the supercharger and illustration of supercharger units without the rotor. Aeroplane, Aeronautical Engg. Supp., November 10, 1937, pages 565–567, 6 illus. Flight, November 4, 1937, page 440, 2 illus., 1 table.

Engine and Fuel Testing

Fait High-Altitude Test Stand. B. Rabinovitch. Description covers: equipment for cooling exhaust gases, reducing the pressure, circulating air in the tunnel, and for humidifying the air; engine test-stand installation; fuel, oil and water systems and supply apparatus; central control table; and operations. L'Aérophile, October, 1937, pages 233–234, 3 illus., 1 table.

Fuels and Lubricants

Aircraft Operation with Fuels of 100 Octane Number and Higher. S. D. Heron. History of fuel and concurrent engine development, effect of octane number on engine performance, relation of engine and aircraft performances, and relation of engine performance to aircraft earning capacity. A. P. I. paper. Oil & Gas Jour., November 12, 1937, pages 185–186, 188–190, 192, 3 tables.

Aircraft Radio

Aero Radio Digest. RCA Models AVR-7D, E, F, and G aircraft radio receivers and AVT-7B transmitter. Blaw-Knox radio range towers. Bendix antistatic D-F loop installed in Northwest Airlines fleet of Sky Zephyrs. Demonstration of R.C. 5 automatic radio compass (Busignies) by the International Telephone and Telegraph Company. Communication Development Corporation's radio trainer for instruction in radio navigation, direction finding, and instrument landing. Newly assigned U.H.Fs. Simultaneous nine-channel radiotelephony on short and ultra-short waves developed in England. Stancor 10-Aero aircraft radio transmitter. Universal lightweight microphone developed for aircraft. Army Air Corps aircraft automatic landing demonstration. Aeronautical Radio automatic battery charger, and antenna windsock. Short descriptions. Aero Digest, November, 1937, pages 81–83, 9 illus.

Aircraft Radio. New R.C. 5 radio compass demonstrated at Newark, RCA transmitter and receiver, and Aeronautical Radio trailing-wire antenna reel. Long description of compass demonstration, shorter descriptions of others. Aviation, November, 1937, pages 44–45, 4 illus.

Testing Aircraft Radio Transmitters. In the two new test rooms of General Electric Company effect on radio transmitting equipment of wind, rain, sleet, and snow, Arctic and tropical temperatures, six-mile altitudes, and power dives can be determined. Description of rooms. Aero Digest, November, 1937, page 72.

Ultra Short Waves for Air Navigation. H. W. Roberts. For more precise radio navigation of aircraft radio aids will employ the ultra-short-wave band from 1 to 10 meters. Closer approach to precision navigation, independence from static conditions and other phenomena affecting long-wave beacons, and reduction in costs, weight, and overall dimensions are predicted. Essential phenomena associated with radio waves of different lengths and manner of their propagation, as well as aircraft and ground equipment and antennas are considered. Reference is made to an experimental collision warning device employing radio micro-rays (15 mm.) which is being successfully tested today on the S. S. Normandie. Aero Digest, November, 1937, pages 66, 71, 5 illus.

Automatic Landing for Airplanes. Cutaway drawing of an airplane shows location of equipment used in the Army Air Corps automatic landing system. Operation outlined. Scientific Am., December, 1937, page 326, 3 illus.

An Improved Medium-Wave Adcock Direction-Finder. R. H. Barfield and R. A. Fereday. Direction finder working over the wavelength range 750 to 2000 meters (frequency 400 to 150 kc.) with a pickup factor between 3 and 5 meters. Bearing can be taken on a field strength of 10 microvolts/meter with swing of less than 1°. From Radio Department, National Physical Laboratory. Radio Research Board program. Jour. Instn. Electrical Engrs., November, 1937, pages 676–681, 6 illus.

Kites to Carry Radio Antenna. Kite designed by H. Leuderitz to carry radio antenna after an emergency landing of aircraft at sea. Brief note. Scientific Am., December, 1937, page 371.

A Long-Range Direction Finder. Remarkably accurate long-range direction-finder system developed by Pan American Airways has a stationary antenna array approximately 150 ft. square. Direction of incoming signal is determined by a search-coil goniometer, and the system uses short waves for radio direction on ranges up to 3800 miles. Brief note. Scientific Am. December, 1937, page 372.

A Short-Wave Adcock Direction-Finder. R. H. Barfield and W. Ross. Short-wave aural direction finder of coupled type having a working wavelength range from 35 to 70 meters (frequency 8.6 to 4.3 Mc.). Construction, performance, polarization error, pickup factor, instrumental error, and experiments in measuring these properties. Jour. Instn. Electrical Engrs., November, 1937, pages 682–690, 5 illus., 19 equations.

Meteorology

The Importance of Observations from the Upper Atmosphere in Long-Range Weather Forecasting. H. C. Willett. Analysis of continuous series of northern hemisphere charts, once daily, carried on without interruption during the past year at M.I.T., and conclusions reached. Bul. Am. Meteorological Soc., September, 1937, pages 284–287.

A Simplified Method of Airplane Soundings. Major W. H. Wenstrom. Method is a reversion to earlier sounding devices and was designed to obtain same result as an aerograph sounding. Standard airplane altimeter, Taylor scale-on-stem glass thermometer of liquid type, and Selsi precision hygrometer are used. Bul. Am. Meteorological Soc., September, 1937, pages 281–284, 3 illus.

Weather or No. Standardization of weather reports throughout the World, and steps towards International organization of Atlantic weather reports were highlights of the International Meteorological Committee meeting at Salzburg. Wind speeds in all code weather reports will be standardized in km./hr. and temperatures in Centrigrade. Brief note. Aeroplane, October 13, 1937, page 437.

Weather and Sunspots. H. T. Stetson. Relationship between sunspots and weather under investigation for assistance in long-range weather forecasting. Scientific Am., November, 1937, pages 276–279, 3 illus.

Aeronautical Industry and Production

From Japan's Industrial Front. Proposed restrictions on importation of aircraft, engines, and parts. Military authorities are said to consider that domestic industry has attained "international level" and that imports should be restricted to experimental units. Showa Aircraft Engineering Company is going to build several plants for manufacture of engines and fuselages and is endeavoring to purchase manufacturing licenses for foreign aircooled inverted-vee engines. Brief note in article on Japanese automotive industry. Automotive Industries, December 4, 1937, page 793.

Getting Going at the Shadow Factories. Figures quoted show the success of the Shadow Scheme of the British Air Ministry. Descriptions cover the new Rootes, Daimler, Standard, Rover, and Austin factories producing aircraft engines and airplane frames, and the production methods and machine tools employed. A year ago last August, and in certain instances even more recently, these factories were green fields. Today they are equipped with 82 to 100 percent of their machine tools and are manned and producing. Long article. Aeroplane, November 4, 1937, pages 529–539, many illus. Flight, November 3, 1937, pages 445–448, 448a, 449, 7 illus.

The Government "Shadow" Factories. Aircraft and engine parts are produced by the Austin, Daimler, Rootes Securities, Rover, and Standard Motor companies at a steadily increasing rate. Each manufactures components of the Bristol Mercury VIII engine. Half will be assembled and tested at the Austin factory and rest at a Bristol government factory. Austin is also constructing frames for the Fairey Battle and Rootes the Bristol Blenheim. Long description of factories and components produced. Engineering, November 5, 1937, pages 511–514, 5 illus. Engineer, November 5, 1937, page 499.

Photographs of interior of plants. Flight, October 28, 1937, page 423, 4 illus.

Douglas Keeps Northrop Shut: Air Corps Enters Long Battle Between Management and C.I.O. Review of situation, and parts of the official notification from Major K. B. Wolfe to the Douglas Company regarding indicated sabotage in the Northrop plant. Aviation, November, 1937, page 59.

Production and Deliveries of Airplanes and Engines for First Eight Months of 1937 Compared to Same Period in 1936. Table showing military as well as commercial production and deliveries. Western Flying, November, 1937, page 27, 1 table.

War-Time Contracts. C. C. Fenn. Tentative plans for prompt production and fair prices. Continued. Army Ordnance, November–December, 1937, pages 154–157, 1 illus.

Preparedness in England. L. A. Codd. Analysis of principles, methods, and policies now being used for mobilization of England's peacetime industry to meet a defense program. Newly-organized munitions-production agencies under the War Office are discussed in this issue. To be continued. Army Ordnance, November–December, 1937, pages 143–146.

Americanizing Australia. License granted to Commonwealth Aircraft Corporation to manufacture Pratt and Whitney "H" aircraft engines. Brief note. Aeroplane, October 27, 1937, page 498.

Nationalizing the French Aircraft Industry. Explanation of reasons for the nationalization of the French aircraft industry, and description of firms involved. Aeroplane, November 17, 1937, pages 582–583.

Pilots

Modern Problems of Aeronautical Medicine. P. A. Gemolli. Outline only of problems being studied in regard to effects of high altitudes and acceleration, and local orientation, and referring to a Mosso doctrine. Such research is being undertaken in the United States, Poland, Hungary, and Germany. Author is president of the Medical Commission of the R.U.N.A. Very brief abstract. L'Aerotecnica, August–September, 1937, page 770.

Oxygen-Lack at 10,000 Ft. Before, during, and after the long 125-hour assignment in a Pan American Clipper to Manila Dr. R. A. McFarland found the whole crew functioned with a high degree of physical and mental fitness. Brief note on Aero Medical Society paper. Aviation, November, 1937, page 56.

Princess Mary's Royal Air Force Hospital. C. M. McAlery. Facilities of the hospital at Halton, and the R.A.F. Medical Service, with a reference to the R.A.F. Institute of Pathology and Tropical Medicine. Aeroplane, October 20, 1937, pages 475–477, 9 illus.

Specialized Training. Course of instruction given transport pilots at the British Airways' school. Flight, November 18, 1937, pages 492–493.

Visual Standards for Aviators. Wing Commander P. C. Livingston. Licensing of one-eyed pilots is discussed in a letter by a consultant in ophthalmology, Royal Air Force. Aeroplane, October 20, 1937, page 494.

Air Forces

Aviation in Venezuela, Columbia and Ecuador. F. Hughes. References to military equipment, and description of commercial aviation. Aeroplane, October 20, 1937, page 483.

Economic and Financial Aeronautics. Rumania has purchased 30 Nardi F. N. 305 airplanes from Italy. Chile has spent 38 millions in Italy and 58 millions in Germany. Turkey has paid $320,000 for forty Grumman amphibians. Afghanistan has acquired sixteen Alfa Romeo reconnaissance airplanes and six Breda 25 and 28 training airplanes. Brief references. L'Aerophile, October, 1937, page 225.

Foreign Service News—Equipment. First of a series of twelve S9 two-seater trainer biplanes (Menasco B6 engine) has been completed by Fokker for the Netherlands Naval Air Service.

New Russian bomber (830-hp. M34 engine) armed with four machine guns and cannon, and having an estimated speed of 210 m.p.h. has been reported.

Italy has sold 20 Breda 65 attack machines and nine Nardi F.N. 305 trainers to Chile and 16 Ro. 37 reconnaissance biplanes and six Breda trainers to Afghanistan. Brief references. Flight, November 11, 1937, page 474.

ARGENTINA

The Four Winds. Twenty Focke Wulf training machines have been delivered to the Argentine military authorities who have acquired the right to build them in the military airplane factory at Cordoba. Brief reference. Flight, September 2, 1937, page 231.

AUSTRALIA

Modernity of the R.A.A.F. Types of aircraft of the Royal Australian Air Force. Very brief note. Aeroplane, August 25, 1937, page 217.

AUSTRIA

The Four Winds. Five Italian Romeo reconnaissance biplanes have been bought by the Austrian Army. Brief reference. Flight, October 28, 1937, page 420.

CHINA

PX's. First aviation gas, about 7500 drums, has been shipped to China. Brief reference. Western Flying, November, 1937, page 36.

DENMARK

D.21s for Denmark. Danish Army Aircraft Factory has started work on a batch of Fokker D.21 single-seater fighters. With Bristol Mercury VII (830 hp. max.) the airplane is said to be capable of 276 m.p.h. and to climb to 19,700 ft. in about 7½ minutes. Brief reference. Flight, October 21, 1937, page 406.

EGYPT

More Gallant Allies. Plans for strengthening Egypt's defenses. Apparently a large invasion from the west on the thickly-populated Nile Valley is feared. Brief note. Aeroplane, August 25, 1937, page 215.

FRANCE

Organization for Accelerating the Production of Equipment. Decree of the French Air Minister of October 15 fixing the responsibilities of the chief of the staff and Service Technique for the design, production, and modification of military equipment. Les Ailes, October 21, 1937, page 3. Aeroplane, October 27, 1937, page 497. (Brief note.)

GREAT BRITAIN

A. C. Training. British Army cooperation units worked with all Army Commands during the past quarter as part of Brigade, Divisional, Inter-Divisional and other exercises. Troop-carrying exercises included 169 flights and 2960 troops were carried. Short description of these and other exercises. Flight, October 28, 1937, pages 431–432.

Closer Co-operation. Five cabin two-seater Autogiros with direct-start characteristics and Siddeley Civet engine have been ordered by the Air Ministry for transport of Army Staff officers to and from headquarters. Very brief editorial. Flight, October 21, 1937, pages 394–395.

The Luftwaffe and the Royal Air Force. Visit of German air force officers to R.A.F. stations. Aeroplane, October 27, 1937, pages 505–507, 4 illus. Flight, October 28, 1937, pages 426c, 426d, 427, 7 illus.

Air Strength in the Mediterranean. Twelve flying boats are stationed in the Mediterranean at present. Brief references to bases used for their operation, to an accident to one in taking off from Malta, and to the 18 flying boats operated by Imperial Airways over the Mediterranean. Aeroplane, November 10, 1937, page 554.

Army Co-Operation Training. Air cooperation exercises with the Army covered troop carrying, communication between tanks and aircraft, strategical reconnaissance, and air photography to study effects of camouflage. Brief note. Aeroplane, November 3, 1937, page 527, 1 illus.

Civil Service. British Service pilots are to be attached to Imperial Airways and British Airways for individual out and home trips. The first will be bomber pilots who will study radio control and navigation as well as blind take-offs and approaches using ultra-short-wave receivers, and avoidance of ice-forming layers. Brief note. Flight, November 11, 1937, page 477. Aeroplane, November 10, 1937, page 572.

With the Fleet Air Arm in Scottish Waters. A. E. Barlow. Autumn cruise of the Home Fleet to Invergordon and Rosyn. Dive-bombing procedure, position of N.C.O. pilots, cruisers and aircraft taking part, Fleet Requirements Squadrons, torpedo runner attack on a ship, spotting exercises, the splash target, and squadrons of the aircraft carrier "Furious." Aeroplane, November 17, 1937, pages 591–594, 5 illus.

The State of Expansion. Twenty-five new R.A.F. stations and armament training camps have been opened and 21 new sites selected. Some 3850 pilots have been chosen and 3500 more have already completed or are in the course of training. Number of airmen entered total 25,200 and about 4840 boys are being trained as apprentices. Progress of R.A.F. since May, 1935. Brief reference. Flight, October 28, 1937, page 431.

The Waziristan Campaign. Further details of R.A.F. participation in this campaign. Second note deals with R.A.F. operations in the Adonga District of the Sudan. Aeroplane, October 27, 1937, pages 503–504.

HOLLAND

Netherlands Defence. Provisional orders placed for more than 100 machines will probably include: 34 Fokker D. 21 fighters; 34 improved G. 1 two-seater twin-engined destroyers; 26 T. 5 heavy bombers, half of which are already in production; and 18 Dornier flying boats for the Netherlands Indian Air Force. Last are very latest three-engined types and will be built under license by the Aviolanda works. Brief note. Flight, November 4, 1937, page 454.

RUMANIA

Full Dual. Three specially equipped D.H. Dragonfly trainers recently completed for Rumania have standard two-way and D.F. radio equipment and are fitted with fully duplicated and very complete blind-flying panels. Photographs of instrument boards and radio equipment. Flight, November 11, 1937, page 470, 2 illus.

SWEDEN

Sweden Steps Out. All military aircraft for Sweden will be built in that country. Cooperative production of Northrops is planned. Over 41½ million kroner is asked for the Air Force on the 1938–39 budget. Brief reference. Flight, October 21, 1937, page 406.

TURKEY

Turkey wants 1000 planes for its air force by the end of 1939. Extensive orders have been placed in the United States, principally with Glenn L. Martin. Brief reference. Aviation, November, 1937, page 64.

British Aeroplanes for Turkey. Two new Monospars have been purchased by the Turkish Air League for instruction in parachute jumping. Aeroplane, October 6, 1937, page 410.

U. S. A.

Our Use of Air Power. Maj. Gen. F. M. Andrews. The GHQ Air Force as an instrument of defense. Analysis of its requirements, purpose, functions, and operation. Army Ordnance, November–December, 1937, pages 137–142, 5 illus.

A Significant Order. The 176 Consolidated patrol-bomber flying boats ordered by the U. S. Navy "will be called upon to operate virtually as part of the Fleet. Apart from reconnaissance work they will be exercised as bombers against the vanguard of an enemy force." British comment on recent Navy orders transferring destroyers in Scouting Force to the Battle Force, all patrol plane squadrons, minus the Utility Wing, to the Scouting Force from the Aircraft Base Force, and administration of Utility Wing to the U.S.S. Rigel, making the plane unit integral part of Base Force. Flight, October 21, 1937, p. 406.

Technical Notes. War Department of the United States has allotted a credit of $200,000 for the study and improvement of the gyroplane. Brief reference. Les Ailes, October 7, 1937, page 8.

U. S. S. R.

A Soviet Air Display. At the Soviet annual air display August 17, a number of gliders were towed to 2500 ft. in flights of three, each flight coming down in close order. Seventy-five men jumping from three machines landed in front of the official box. New four-motored bomber and a four-motored flying boat were shown. Very brief note. Aeroplane, August 25, 1937, page 217.

Air Warfare

Aircraft vs. Battleships. "Bombers attacking from several directions in synchronized combination with submarines will constitute a menace to shake the stoutest heart, since no gunner can shoot in several directions at once . . . falling at an enormous velocity, in one or many long strings or fanwise . . . or diving from all directions . . . We should flatten out down between battleships and their antisubmarine screen of cruisers and destroyers . . . A small force, such as four or five scouting battlecruisers, each costing as much as forty of my aircraft and carrying thousands of men on board, would stand a very good chance of being annihilated if attacked, each by four or five torpedoplanes simultaneously." Examination of the pros and cons, defensive patrols, and a fleet's vulnerability. Flight, November 4, 1937, pages 448b–448d, 449, 5 illus.

Lessons from Spain. Fabric-covered wings have been destroyed by air concussion of bombs exploding 50 ft. away. Metal-covered machines are less vulnerable but vent holes should be provided in the fuselage to release compressed air due to a bomb exploding nearby. Petrol tanks 13 ft. underground and covered by a layer of sandbags 5 ft. deep have withstood direct hits from 440-lb. bombs. Results with incendiary bombs were not up to expectations, twin-engined bombers are very vulnerable to right-angled, as well as tail attack. These and other points are covered in a brief note from Revue de l'Armée de l'Air. Flight, November 11, 1937, page 474.

Flying Searchlights. W. S. Shackleton's suggestion that special aircraft be designed to carry powerful searchlights to the height at which raiders are likely to be flying. Brief editorial on means of securing the cooperation needed between searchlights and defending fighter airplanes. Flight, September 2, 1937, page 225.

Aerial Bombardment. Cy Caldwell. "To be of real value, air forces must be trained to a much higher degree of efficiency than anything we have heard of yet in China or even in Spain. And they must be used strategically." Use of Air Power in China and Spain as an army auxiliary and poor markmanship are criticized, and comments made on the superiority of the Russian organization in Spain compared with that of the combined German and Italian organizations.

The Chinese situation is placed in the United States, Boston substituted for Shanghai, and strategic as well as tactical uses of Air Power in defense and offense are demonstrated. Aero Digest, October, 1937, pages 30–31, 101–102, 2 illus.

Dive Bombing Indicated. The Danes intend to abandon this form of attack because the Germans have reached the conclusion that the highest velocity attainable by the bomber is insufficient to increase materially the penetrative power of the bomb and the method is unduly costly. Recent issue of German Air Ministry orders for rewards to finders of towed targets, mentions a dive-bombing towed target. Brief reference. Flight, October 28, 1937, page 432.

Flying in Spain. Government forces recently used six Martin bombers and various fighters, apparently Russian copies of American designs. Russian low-wing monoplanes are said to be more like Gee Bees or Granvilles rather than Boeings. Brief note. Aeroplane, October 20, 1937, page 366.

Various Notes. Probability of an airplane making a hit on a target while being fired on by one of the new Bofors rapid-fire 40-mm. guns. Results of calculations made by a Swedish ordnance expert. Brief abstract, Revista de Marina, Peru. U.S. Naval Inst. Proc., November, 1937, page 1666.

Miscellaneous

2100-Gallon Fueling Trucks. Truck developed by Standard Oil Company of New Jersey and United Air Lines has four separate compartments, three for 1900 gal. of gasoline and one for 200 gal. of oil. By means of a two-way system oil or gasoline can also be pumped from storage or airplane tanks. Oil and gasoline delivery systems are separate. Short description. Aero Digest, November, 1937, page 74, 1 illus.

Blind Flying on the Ground. Wing Commander G. W. Williamson. A large number of American Link trainers made for the R.A.F. are fitted with Lorenz blind landing indicators. Details of trainer, its immense possibilities, and modifications for different purposes. Flight, October 28, 1937, pages 416–419, 4 illus.

The Missing Link. F. D. Bradbrooke. Link trainer in use for training pilots of British Airways. Equipment for Lorenz approaches, the Crab, and trainer operation are described. Aeroplane, November 10, 1937, page 475, 1 illus.

On the Lilienthal Gesellschaft. C. G. Grey. Article deals mostly with comments on Munich where the meeting was held and on a visit to the B.M.W. works. Aeroplane, November 10, 1937, pages 555–559, 2 illus.

The Case for an Objection. Further objections to F.A.I. approval of the Russian distance record of 6305.7 miles from Moscow to California. Analysis of figures on the ANT-25 given by American experts who examined airplane after it landed. The second issue continues the discussion. Aeroplane, November 3 and 10, 1937, pages 526 and 553–554.

Candid Opinions Predominate at Aircraft Meeting Sessions. Account of S.A.E. National Aircraft Production Meeting, October 7 to 9. S.A.E., November, 1937, pages 14, 24–26.

The Effect of Lightning. Report regarding effect of lightning striking a Junkers Ju 86 (heavy-oil engines) during delivery flight in Australia. Only damage was a small piece melted away from outer covering of port rudder. Brief note. Aeroplane, August 25, 1937, page 216.

The French N.A.C.A. Will Come into Existence in 1938. G. Houard. The G.F.D.R.A., "French Organization for the Development of Aeronautical Research," has been organized on the same principles as the N.A.C.A. and D.V.L. Object and points in the program are discussed. Les Ailes, November 4, 1937, page 8.

All Hands to the Pumps. Another British government competition for a design of a commercial airplane is in the wind. Previous airplane competitions are reviewed and suggestions made as to how the government should operate the proposed one. Aeroplane, October 20, 1937, page 468.

Jean Batten Succeeds Again. Flight from Port Darwin to England was made in a Percival Gull (Gipsy Six) in 5 days 18 hours 15 minutes. Account of flight and equipment used. Flight, October 28, 1937, page 419, 2 illus. Aeroplane, October 27, 1937, page 516.

Record-Breaking Plans. Suggestions for obtaining the absolute speed record for Great Britain, including three for simplifying the problem of torque to beat the present waterplane record. Aeroplane, October 27, 1937, page 495.

What the Engineers Said. F. Miller. Account of S.A.E. National Aircraft Production Meeting in Los Angeles, October 7, 8, and 9. Western Flying, November 1937, pages 8–10, 23–24.

Similar account. Aviation, November, 1937, pages 24–25, 67, 76, 78.